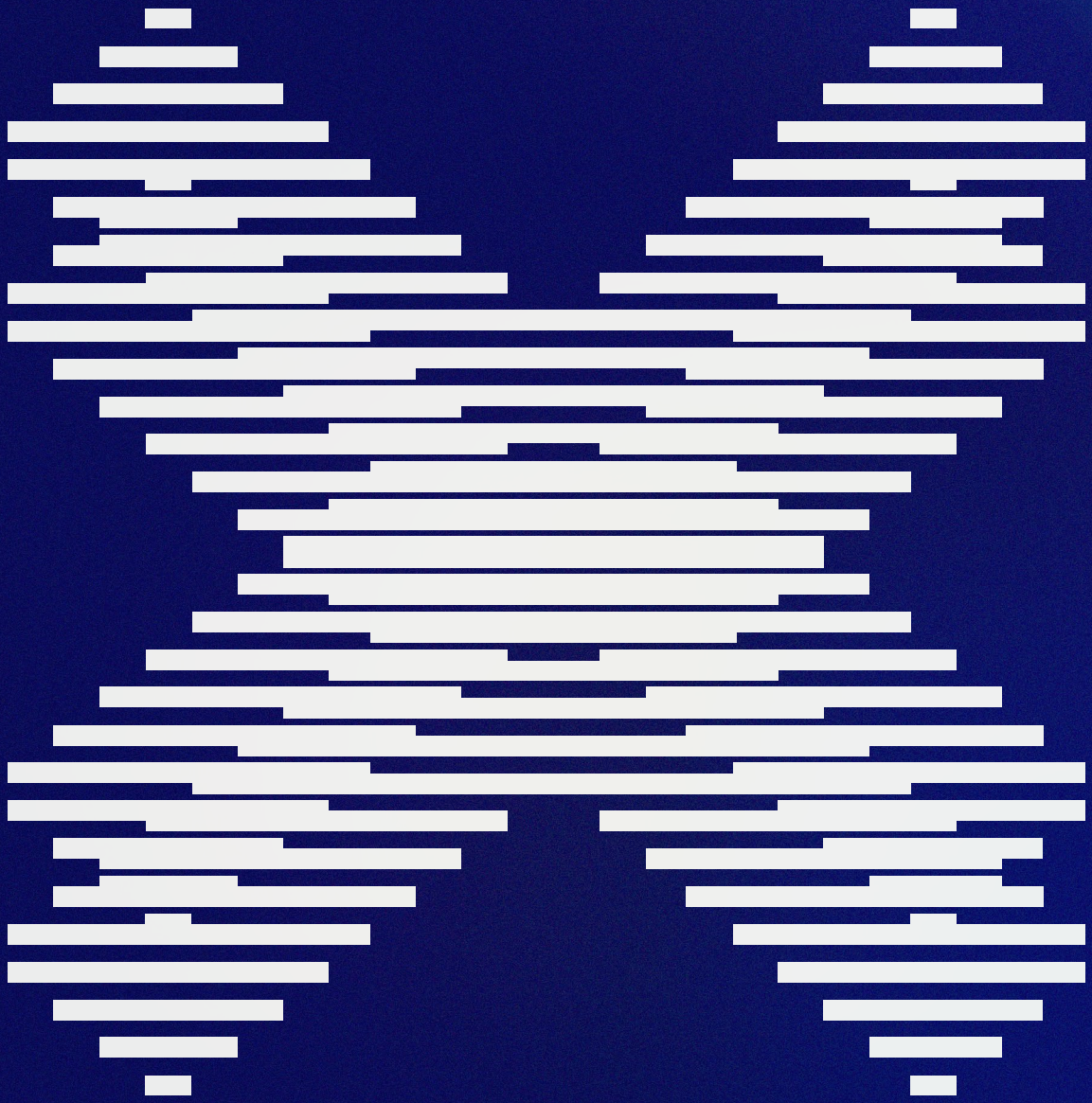
xCoAx 2025



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Papers

14 Moritz Alan Huson, Lena Gieseke
Datamorphism: Data Art of the Other-Than-Human

31 Dejan Grba
Insidious Imaginaries: A Critical Overview of AI Speculations

54 Matthew Blanco, Todd Linkner
Providing Form to Function: Exploring Code Through Visualization

65 Tyler Grimes
Fauxtanical: Co-creation with the More-than-less-than-human

80 Isaac Clarke, Theo Papatheodorou
BackChat: When AI Learns Language in Reverse

93 María José Ríos Araya, Ricardo L. Vega Mora
Transmutations: Aesthetic Explorations for the Subjective Signification of Signals and Data

104 Nina Wenhart
Operativity: From Images to Archives

115 Yesica Duarte, Puneet Jain
Challenging Disability and Interaction Norms in XR: Cooling Down the Empathy Machine in Waiting for Hands

125 Laura Devendorf, Alex McLean, Vernelle Noel, Iván Paz, Anu Reddy, Elizabeth Wilson
What is Algorithmic Pattern? Reflections on a Salon

136 Eke Rebergen
Algorithms and Environmental Concerns: From Game Design to Creative Resistance

154 Martin Gordon
Trapped in the Metric Tar Pit of Common Time

168 Kim Frederic Albrecht
Artificial Worldviews

184 Ellen Pearlman
The Dybbuk, The Loab, Latent Space and Multi-Modal Artificial Intelligence

196 Ludovica Schaerf, Ana Zapata, Darío Negueruela del Castillo, Iacopo Neri
Between the Discrete and the Infinite: Attention and Latent Space Metaphors in Borges and Calvino

215 Xinyu Ma, Clea von Chamier-Waite
Material Agency in Systems of Art: Reflections on Theatricality, System Aesthetics, and Nonhuman Turn

235 Jonathan Impett
Apollo e Marsia: Time and Memory under Tension

245 Magno Caliman
Imagining and Inventing Bespoke Devices for Experimental Sound Practices

253 Miguel Crozzoli, Thor Magnusson
Data Perceptualization through Affect in Dark Sonification

270 Rafael Maia
Timbre: Transforming Perception into Sonic Expression

Artworks

287 Rosemary Lee
A Structural Plan for Imitation: Engines of Differentiation

291 César Escudero Andaluz
An Atlas to Track Blockchain Colonialism

296 Julian Palacz
Do Not Drop (Parcel Series)

301 Lucia Bergamaschi, Tomáš Javůrek
Garden Me Tender

308 Shinji Toya
Lives of Your Smartphones

318 Francesca Morini, Kim Frederic Albrecht
The Hyper-visual Times

327 Derek Curry, Jennifer Gradecki
Generative Persuasion

332 Gaston Welisch
Botter: Social Media for Bots

338 Tore Knabe, Jonathan Harth
A Reverse Turing Test

341 Pedro Costa
Cistem Not Found: A Project on Mutable Gender Possibilities in AI

353 Beverley Hood
MOTHER: Generative AI Photo-film

356 Jérémie Wenger
Subwords

366 Brass Art: Chara Lewis, Kristin Mojsiewicz, Anneké Pettican, with Annie Mahtani
This Voice; This Life; This Procession

371 Christian Geiger, Ivana Družetić-Vogel, Laurenz Ulrich, Leon Repp, Christian Zimmer
Oneironautica III: Estrangement

380 Sofia Taipa
Being Within

386 Daniel Bisig, Philippe Kocher
Motionforms: A Kinetic Light and Sound Installation

Performances

392 Jules Rawlinson
Pulsar Threads

397 Christos Michalakos
AETHRAKHTHON: Structuring Electroacoustic Improvisation and Performance Using a Game Engine

400 Alex McLean, Elizabeth Wilson
Modulating Time

404 Daniel Bisig, Ephraim Wegner, Aaron Bühler, Daniel Fetzner
Sonosphere: A Spatial Music Instrument for Human and Artificial Dancers

411 Rudolf Arnold
Translating Desire

419 Angela Brennecke, Andreea-Cristina Mircea, Elena Vasilkova, Aydin Thill, Anna Ferro, Joel Schäfer, Lisa Passing
Currents & Tides: An Exploration of Generative Music in Three Acts

Foreword

Fait accompli logic, or the logic of the accomplished fact, is a strategy based on presenting a decision or action already brought to completion, leaving others with little to no choice but to accept it. This rationale carries a somewhat manipulative and unilateral connotation, because it essentially aims at forcing acceptance through inevitability.

The most upsetting events that have recently brought immense turmoil and pain to the world are marked by *faits accomplis*: acts of terrorism and military aggression have abruptly forced many people across different regions to confront radically altered lives, where survival and the effort to cope with profound loss have become their primary, if not sole, focus.

In this disquieting scenario, where the prospect of a global war no longer seems like a dystopian fantasy, even those whose lives are not directly at risk appear compelled to accept a considerable number of "facts". From a sociological perspective, this includes newly imposed regulations on migration flows, asylum policies, citizenship laws, and visa and work permit frameworks. From an economic standpoint, it encompasses the implementation of new tariffs and the emergence of international conflicts that further drive up the cost of everyday goods, already strained by persistent global inflation. From a scientific and technological perspective, it involves increasing difficulties in securing funding for research, as well as a precarious management of global infrastructures, controlled by a select few yet capable of impacting millions.

All things considered, we at xCoAx consider ourselves incredibly fortunate to organize an event where artists, performers, and researchers come together not only to present their work but, crucially, to discuss it. We place particular emphasis on the *discussion* aspect, as everything included in the programme, be it a paper, a performance, or an artwork, is open to dialogue and debate. The fallible and ever-evolving nature of scientific theory, the postmodern skepticism toward fixed meaning and singular authority in art, and the relational aesthetics that understands performance as a co-constructed experience are all relatively recent yet profoundly important achievements of human culture. These are values we deeply cherish and are committed to upholding for as long as we can.

One might wonder whether it makes sense to work on computation, communication, and aesthetics in a world where the most advanced facets of computation are applied to warfare, where the very essence of communication is threatened by deep fakes and echo chambers of manipulation and radicalization, and where aesthetics is increasingly instrumentalized for commercial persuasion and reduced to metrics of engagement.

Of course it does. In fact, it makes sense *now* more than ever, to fight the logic of accomplished facts.

Thank you for bringing your knowledge, your critical thinking, and your free spirit to xCoAx.

Let the meaning of the X, as crossroads and exchange, shine ever more brilliantly.

X

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Papers

Datamorphism: Data Art of the Other-Than-Human

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To comprehend our era of ecological crisis, novel forms of artistic engagement with other-than-humans are urgently needed. A common mode through which art engages with the other-than-human is anthropomorphism. We analogously introduce the concept of "datamorphism" as a bridge connecting data, the other-than-human, artistic practice, and audience perception of data art. Specifically, datamorphism describes how data properties and our understanding of data shape the form and reception of data-artworks and the other-than-human represented. We establish criteria that define datamorphism and examine an exemplary artwork featuring data-driven representations of other-than-humans. Our research reveals that the concept of datamorphism enables us to systematically analyse data art and its reception and may support artists in representing other-than-human beings and phenomena beyond anthropomorphic (and perhaps anthropocentric) interpretations.

1. Introduction

On a Sunday afternoon, a visitor strolls through a contemporary art exhibition. A painting catches their attention: Colours of varying hues and saturation form complex patterns on a canvas devoid of discernible content, and the visitor's emotional response is unguided and individual. Then the visitor reads the description of the artwork. What they thought were abstract patterns created by the artist's imagination are, in fact, representations derived from a dataset. The artist did not decide upon each stroke freely; instead, they referred to numerical data to shape the artistic visual representation. Knowing that the artwork is based on data, one might expect the visitor's perception of the art to shift. They may attempt to understand the mapping from the data to the visual representation, constructing theories on what the data could signify. Furthermore, as the data points to a real-world phenomenon, the visitor perhaps believes they are perceiving and understanding an objective truth.

We introduce datamorphism to describe the perceptual shift that occurs when viewers learn that an artwork is data-based. Datamorphism includes examining how data morphs in art and whether there are common patterns in audience perception, particularly regarding

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Keywords data art, data visualization, computational art, anthropomorphism, post-humanism

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Fig. 1. *"More Than Us"* by Julie Freeman (Freeman 2022). This artwork translates climate data into an animated composition where geometric shapes, inspired by Suprematist art, move through data landscapes both randomly and purposefully, illustrating the interplay between chance and pattern in complex data. We introduce the concept of datamorphism to explore the complex relationships between data, its artistic representation, and the audiences perception in such data art. All image rights are with Julie Freeman and Hiscox.

perceived truthfulness. For artists, datamorphism represents the challenge of artistically rendering complex data and engaging viewers affectively. In developing the concept of datamorphism, we draw inspiration from anthropomorphism in art and its approach to making other-than-human entities understandable and creating empathy for them by attributing human traits (Dolins 2017).

Suppose an artwork represents over 5000 data points from the Kepler Space Telescope, illustrating the sizes, orbital periods, and types of exoplanets. While the raw data itself may be incomprehensible to a casual viewer, the artwork summarises, abstracts, interprets, and visualises it. Although scientific details may be overlooked, the viewer may intuitively sense the vastness and complexity of galaxies. The abstract nature of the painting transforms into an interpretive space of exoplanets for the viewer to explore, blurring the line between data and phenomenon.

While methodologically, datamorphism aligns with anthropomorphism by morphing other-than-human entities from a particular vantage point (in the case of anthropomorphism, by attributing human traits; in datamorphism, by driving representations through the scope of data), there is potential in datamorphism for including other-than-human agency. Bruno Latour's Actor-Network Theory (Latour 2005) serves as the theoretical foundation for this potential, attributing agency, impact, and relationships to non-human entities. We recognise other-than-human beings and phenomena as equal actors.

Our main contribution is the novel concept of datamorphism through which we examine how data-based art mediates between abstract information and human perception, while challenging anthropomorphic aesthetics. Datamorphism helps to understand both the perceptual shifts in viewers and the artistic potential to create meaningful connections with other-than-human phenomena through data. To investigate and establish the concept of datamorphism, we build a theoretical foundation by discussing anthropomorphism and art (Section 2), data, dataset sizes, data types, and data's relevance (Section 3) before defining datamorphism and its properties (Section 4). We conclude with a critical discussion of our research (Sections 5 and 6).

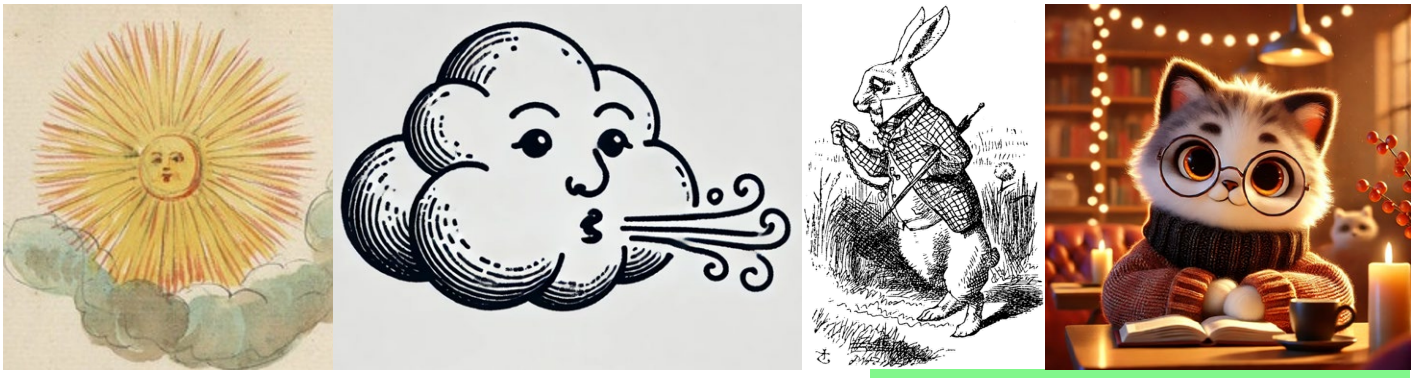


Fig. 2. Artistic examples assigning human traits to the other-than-human, historic and contemporary, from left to right: Thesaurus of Alchemy, ca. 1725, author unknown, public domain; ChatGPT 4o result of “cloud with a face blowing wind” prompted by the authors; The White Rabbit in Alice’s Adventures in Wonderland, 1865, John Tenniel, public domain; ChatGPT result of “a cute anthropomorphised cat” prompted by the authors.

2. Art of the Other-Than-Human

We explore datamorphism as an artistic concept inspired by anthropomorphism. To establish this connection, we first examine anthropomorphism in art history and then identify technological and scientific advancements and their integration in art as the origins of datamorphism.

2.1. Anthropomorphism in Art

Anthropomorphism can be defined as “[t]he attribution of human traits, motivations, and persona-like qualities to nonhuman animals and/or inanimate objects” (Dolins 2017). The term “anthropomorphism” originated in Greece, where it was negatively connoted as the attribution of human attributes to gods (De Wall 1999). In the context of other-than-human entities, various forms of anthropomorphism exist. One can distinguish more broadly between anthropomorphism “that inaccurately applies exaggerated human characteristics to nonhuman animals” and anthropomorphism that “is used as a critical tool to investigate and construct a framework for understanding both humans and nonhuman animal species” (Dolins 2017).

Anthropomorphism has played a significant role in art and religion (Hollander 2016; Silbergeld 2016; Gheorghiu and Paladino 2024). In stories, other-than-human beings are often used as symbolic representations, such as animal doubles serving as reflections in Norse mythology (Ramos 2014) or to teach moral values in children’s books (Dolins 2017). A prevalent form of anthropomorphism in contemporary stories involves attributing human traits and psychology to animals (Figure 1, the two examples on the right), as seen in literature, such as Alice’s Adventures in Wonderland by Lewis Carroll, The Chronicles of Narnia by C.S. Lewis or complexly structured in The Metamorphosis by Franz Kafka. There are numerous examples in films like Finding Nemo (2003), Ratatouille (2007) or Paddington Bear (2014). Aside from animals, planetary processes such as weather or day-night cycles are also rich with anthropomorphism (Figure 2, the two examples on the left). Crying skies, heaven’s tears,

or the sun and clouds with faces are commonly used poetic descriptions of weather phenomena. In *Wuthering Heights*, Emily Brontë writes: "..., the storm came rattling over the Heights in full fury". In Shakespeare's *Macbeth,* we find: "Come, seeling night, Scarf up the tender eye of pitiful day, And with thy bloody and invisible hand Cancel and tear to pieces that great bond Which keeps me pale!"

Anthropomorphism helps in understanding other-than-humans by shaping our perception of them through the projection of human traits; however, it also exposes the limitations of an anthropocentric viewpoint. Everything around us appears to look and behave like us. Regardless of the subject of an artwork, it is always the result of one or more individuals exploring some aspect of themselves or the world through their subjective experience. The artwork is then also received and interpreted through the individual's subjective experience. Thus, even explicitly anthropocentric art is inherently shaped by the subject engaging with it — there is no singular, intersubjective human experience as such. As embodied beings, we may never fully grasp what it is like to be another species, as illustrated in Thomas Nagel's essay on the subjective experience of a bat (Nagel 1974). We are bound to understand others, human and other-than-human, from our individual human perspective.

2.2. Origins of Datamorphism

In "The Science of Animal Locomotion" Eadweard Muybridge documents his use of the camera to explore the locomotion of various animals (Muybridge 1987). By taking photographs of a galloping horse at regular intervals, Muybridge contributed to two data-driven perspectives for artists to explore. First, by using a camera, he shifted the image creation process away from an individual's interpretation and skill (as is the case in comparison to painting, for example), towards making the image a result of intricate technology. Second, he created a moving image representation that differs in its reception from our unmediated perception of the same event. The images enable us to comprehend the movement, decoupled from the temporality that photography overcomes. Fleeting movements too fast for an unmediated examination become static, inviting intersubjective analysis. While the subject of Muybridge's photographs can still be perceived by humans from an unmediated vantage point, photography constructs novel perspectives. For example, satellite imagery introduced a hitherto unseen perspective on Planet Earth. They provide scientific insight and influence culture too: "In the new consciousness of the counterculture, the NASA photographs of the entire Earth taken from space fuelled a sublime impression of interconnectedness and inter-

dependence between humans and the planet, fostering cybernetic visions of ecological harmony (Franke 2013)" (Ballatore 2014).

Using such data (e.g., photographs, satellite images) resulting from technological advancements does not interfere with anthropomorphism, though. Anthropomorphism relates and contextualises the other-than-human, while technology simply serves as a tool for any form of relating. Art abounds that is neither anthropomorphic nor especially anthropocentric, and that does not incorporate or engage with digital technology. Consider Maria Sybilla Merian's drawings of insects and flowers, John Ruskin's studies of lichen, the works of Cannupa Hanska Luger, the Crochet Coral Reef project, or the paintings of Abie Loy Kemarre, to name a few. Even if art emphasises the other-than-human and artists try to free themselves from a human perspective, we can only remain firmly rooted in our human perspective. Still, if a non-anthropocentric and non-anthropomorphic aesthetic is desired, science and technology can offer means and data to explore previously unseen perspectives. The work of the experiential art collective Marshmallow Laser Feast exemplifies the inclusion of technological and scientific advancements within artistic practice. Their work allows audiences to experience the sensory Umwelt of various creatures and plants (Feast 2024). The concept of Umwelt, introduced by German biologist Jakob von Uexküll, posits that each living being has its own subjective perception of the world based on its physiology (Schroer 2019). Through scientific research, Marshmallow Laser Feast has created experiences that offer speculative windows into the perception of an owl, a mosquito or a tree. These artistic explorations do not induce the lived experience of other beings; instead, they highlight perspectives distinct from our own.

While anthropomorphism offers a bridge to relate to the other-than-human by attributing human traits, technologies and scientific approaches provide data that can shift our perspective and offer alternative ways of experiencing and depicting other-than-humans.

3. Data

Having examined anthropomorphism in art and technological developments as foundations for datamorphism, we now investigate its core element: data. The following discussion explores how the perception of art may shift if it is based on data, analyses different types of data, and examines the broader personal and cultural beliefs that shape our understanding of data.

3.1. The Status of Data

Data have become omnipresent: “[d]ata are everywhere and piling up in dizzying amounts” (Gitelman and Jackson 2013). While data typically describe phenomena, they are increasingly prescriptive, influencing what we see online, who we date, and the policies governments adopt.

The rise of Artificial Intelligence (AI), a prominent technology of the twenty-first century, further emphasises data’s crucial role in modern society, as AI is only possible through the vast amount of available data. Our increasing reliance on data hinges on our perception of what data are. Gitelman and Jackson suggest that while data might seem to precede facts and form the foundation of knowledge, identity, and communication, this perspective can lead to “an unnoticed assumption” about data’s transparency and self-evident nature. They warn that an uncritical enthusiasm for data and its accumulation “can become a faith in [...] their objectivity” (Gitelman and Jackson 2013). This “unnoticed assumption” determines what we conclude from data. Statements are often deemed credible if supported by data, even if the underlying data are not understood. For instance, a data visualisation may lead to what Kosminsky and colleagues aptly describe as “[b]elief at first sight” (Kosminsky et al. 2019).

In computing, data are machine-readable representations of real-world phenomena or simulations. Manovich suggests that to represent a phenomenon with data, one must make three crucial decisions: “[w]hat are the boundaries of this phenomenon?”, “[w]hat are the objects we will represent?”, and “[w]hat characteristics of each object will we include?” (Manovich 2019). These defining questions illustrate the influence of the data collection process and emphasise that data are not neutral, all-encompassing representations that are passively uncovered by scientists, for example. Data are actively generated representations based on assumptions about a subject. They are often considered to be “the fundamental stuff of truth itself” (Gitelman and Jackson 2013). In the following, we explore the implications of this authority that data hold when one engages with them in an art context.

3.2. Data art

What if data were treated similarly to paint, clay, or sound? In her Ph.D. thesis, Julie Freeman defines data as an art material (Freeman 2018). She argues that “data can help illuminate and make sense of things we cannot see, feel, or hear with our human senses,” making it a medium that allows artists to explore the world beyond our senses.

If we consider the work of a painter as arranging paint on a surface, then the work of a data artist might involve translating data in a way that renders them perceptible. We follow Freeman's definition of data art as "[t]ranslations of digital data to create cognitive, physical, and/or sublime artworks." The definition of what constitutes an artwork remains elusive (Viégas and Wattenberg 2007; Eschenbacher 2023). We classify artistic visualisations as data visualisations created by artists with artistic intent, noting that while this may appear tautological, it actually identifies a distinct and meaningful category of work.

Overall, a data visualisation, according to (Kosara 2007; Eschenbacher 2023), must meet three basic requirements: it must be data-driven, have a visual output, and be readable with the intent to communicate information. The authors put visualisations on a spectrum between pragmatic (focused on exploration and analysis) and artistic approaches, with the latter emphasising aesthetics and emotional engagement while still being grounded in data. Artistic visualisations specifically aim to spark curiosity and reflection while expressing particular viewpoints, differentiating them from their more analytical counterparts (Kosara 2007; Viégas and Wattenberg 2007; Eschenbacher 2023).

Perhaps a reason data are not widely considered an art material is their formlessness on the one hand, and being a formal-logical entity on the other hand. Traditional art forms like painting and sculpture are inherently visual, and music is inherently auditory. Data are often simply numbers on a computer screen, offering little of the sensory stimulation that artists otherwise might be used to. In artworks, data need other art materials to embody them. But just as a photograph of a forest can be considered both artistic and informative, so too could a data set describing the nutritional exchange between the trees of the forest, provided it is presented in a way that engages the audience. We may ask, "How is a data representation of some phenomenon or process different from other kinds of cultural representations humans used before?" (Manovich 2019).

We argue that there are no fundamental differences between data representations and other cultural representations. As discussed in Section 3.1, data are collected or created by humans and, with that, are similarly constrained by human assumptions as, for example, photographs or paintings. Nonetheless, data have the potential to reveal perspectives beyond human-centric viewpoints, challenging our traditional ways of understanding the world. We concretise this potential of data art in the following section.

4. Introducing Datamorphism

We introduce datamorphism as a theoretical concept within the field of data art. Datamorphism describes how certain data properties, as well as our understanding of data, uniquely shape both the form and reception of a given data artwork and the other-than-human phenomena represented in it. Similar to how anthropomorphism describes the projection of human traits onto the other-than-human, datamorphism describes the projection of values like truth or universality onto data-artistic depictions of the other-than-human. These values depend on our understanding of data and our data literacy, and they should be examined further at a societal level.

We argue that datamorphism is a necessary concept in discourses surrounding data art. On the one hand, datamorphism highlights data's potential as a source for artistic practice, fostering novel perspectives and understanding of the other-than-human. On the other hand, datamorphism summarises and communicates existing side effects and hidden biases in our work with and reception of data. We must be aware of our seldom-questioned trust in data as an unbiased encapsulation of truth and their broader societal influence. Furthermore, in times of mass extinction, it becomes crucial to rethink how we think of other-than-human beings and phenomena. Novel, creative representations in art and culture are urgently needed to foster a broad ecological consciousness in society.

4.1. Properties of Datamorphism

To further understand datamorphism, we define a set of specific properties, namely, the dataset size, a dataset's meta-communication, machine-generated, perceptible and non-perceptible data, and the data mapping. In the following, we discuss each property in detail.

Dataset Size

A dataset is "a collection of data taken from a single source or intended for a single project" (Merriam-Webster n.d.). The quantity of data collected—measured in data points—varies. A dataset might contain thousands of data points about a single insect, or data on thousands of insects at a single moment. Some datasets are complex and continually expanding.

Datamorphism becomes more pronounced with larger datasets. Data on the movements of a single animal is not significantly different from our own observation of that animal; we can relate to an individual. However, comprehending the movement of thousands of animals, the

scale of trillions of bacteria, or the galaxy goes beyond our perception. As Edmund Burke's "A Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful" notes, "Greatness of dimension is a powerful cause of the Sublime" (Freeman 2018). The enormity and complexity of datasets can provide unique perspectives in data art. The size of a dataset also influences the "so-called truth" (Freeman 2018) we can derive from it. Freeman argues that data visualisations based on different sample sizes present different "views," e.g., from five participants' data compared to from 50,000 participants, and they conclude that the larger sample size substantially increases the likelihood of broadly applicable results (Freeman 2018).

Meta-Communication of a Dataset

The effect and impact of datamorphism depend on an audience's recognition of an artwork as data art and their existing relationship to data in general and the specific dataset in question. Meta-communication refers to the elements in an artwork or its accompanying materials that reveal the presence and characteristics of its underlying dataset. An artist must carefully balance communicating the data-driven nature of their work, its information, and broader context while maintaining the elusive quality that many artists aspire to.

While not an example of an other-than-human dataset, Jason Salavon's "*Home for Sale*" demonstrates the issue of and need for meta-communication. The artwork "[shows] a series of realtor photos of single-family homes for sale in different cities around the U.S." (Viégas and Wattenberg 2007). These were constructed through an averaging technique whereby the pixels of many photos of for-sale houses in different U.S. cities were averaged to create a single image per city. While viewing the images without knowledge of how they were created can be just as intriguing as viewing them with background information in mind, we argue that the potential for a datamorphic reception is only present in the informed reception. An informed reception opens a projection space for the viewer: knowing how the images are aggregates of photographs, a viewer can attempt to deduce meaning. Images such as "*Homes for Sale, Seattle/Tacoma*", which features more blues and greys than the other images in the series, hint at the cloudy weather Seattle is known for. While this deduction can also be made without knowledge of the production process, the presence of data lends the image a degree of accuracy, of authenticity and "realness," characteristic of datamorphism. Data lend the work a degree of authority it may otherwise not possess. It is up to the creativity of the artists and their artistic vision to reveal and communicate their data, which we see as a necessary step for datamor-

phism. We argue that datamorphism is largely an explicit cognitive process where interpretations are made based on the understanding and judgment of the data as a meaningful representation.

Machine-Generated Data

We define machine-generated data as information produced directly from computer processes or applications, generated independently from human intervention at the moment of the data collection. Data generated by taking a photograph or recording an observation involves human agency at the point of creation. In contrast, browser cache data, generated by a computer without direct human involvement, is considered machine-generated. Viewing photography as data collection, nonhuman photography exemplifies the relevance of machine-generated data in datamorphism.

Joanna Zylinska's "*Nonhuman Photography*" discusses how "in the age of CCTV, drone media, medical body scans, and satellite imaging, photography is increasingly decoupled from human agency and human vision"(Zylinska 2024). In the photography project described in the introduction of the book, the photographer James Balog documents the retreat of a glacier. By attaching microcomputers to cameras that he fastened onto rocks, photographs could be taken over several years, something Balog could not do without the help of the technology in use. He created a time-lapse of the retreating glacier, with photographs generated by the computers and the cameras. In doing so, he created a representation of a glacier that goes beyond the anthropocentric perception of time - the resulting photographs, taken by a machine, were not subjected to a human photographer's decision on when to take the picture. The resulting aesthetic is part of datamorphism.

In Véronique Ducharme's "*Encounters*", the movement of animals is automatically photographed. Using remote hunting cameras that trigger the exposure in response to motion and heat, wild animals are photographed without any physical presence of humans. The resulting images, while a result of human invention and artistic intention, also depend on factors beyond the immediate control of the artist. They hand over part of their agency to the functionality of a machine and to the movements of other-than-humans in their habitat.

Machine-generated data arise from a collaboration between human intention and machine processes. Although humans may anthropomorphise or impose their own interpretations during the conceptualisation and design of data collection, the resulting machine-generated data add another layer to the definition of datamorphism. This

is because the data are produced through automated processes that are not influenced by human perception or subjective interpretation at the moment of data creation. Consequently, machine-generated data offer a seemingly less biased representation of phenomena, or rather, one that is decoupled from human agency in the moment of data collection.

Perceptible and Non-Perceptible Data

The type of data artists select shapes not only their vision for the artwork but also the perspectives it can reveal and its potential forms of representation. We differentiate between perceptible and non-perceptible data and their level of abstraction, each of which we further explain in the following.

If we wish to gather data on a forest, we could decide to count the number of trees. Using our understanding of what a tree looks like, we may then walk through the forest, using our visual sense—our eyes—to discern the individual trees, taking note of each one we come across. Later, when we share our findings with others, they will be able to imagine the individual trees, provided they know what a tree looks like. We refer to such data representations of phenomena that humans can perceive with their senses as data of the perceptible.

In contrast, data of the non-perceptible shall refer to data representations of phenomena we are cognisant of, but unable to perceive and therefore collect without technological assistance. For example, through scientific discovery, we have become aware of the presence of fungi in the air (Fröhlich-Nowoisky et al. 2009). However, we cannot observe this directly through our senses, relying on technology to measure the types of fungi and the amounts present. Technology allows us to measure and become aware of phenomena we otherwise would neglect. It also demands trust in and understanding of the technology used to acquire the data and the scientific process more generally. One could argue that part of COVID-19 or climate crisis denial stems from the complexity and perceptual allusiveness of these issues; one cannot see the virus or the climate crisis directly. An artistic representation of climate data, such as rising global temperatures, may alarm us less than a picture of a burning forest, even though both may indicate the same phenomenon. The former represents non-perceptible data, which requires abstract thinking to become legible, while the latter offers an intuitively understandable visual of the effect.

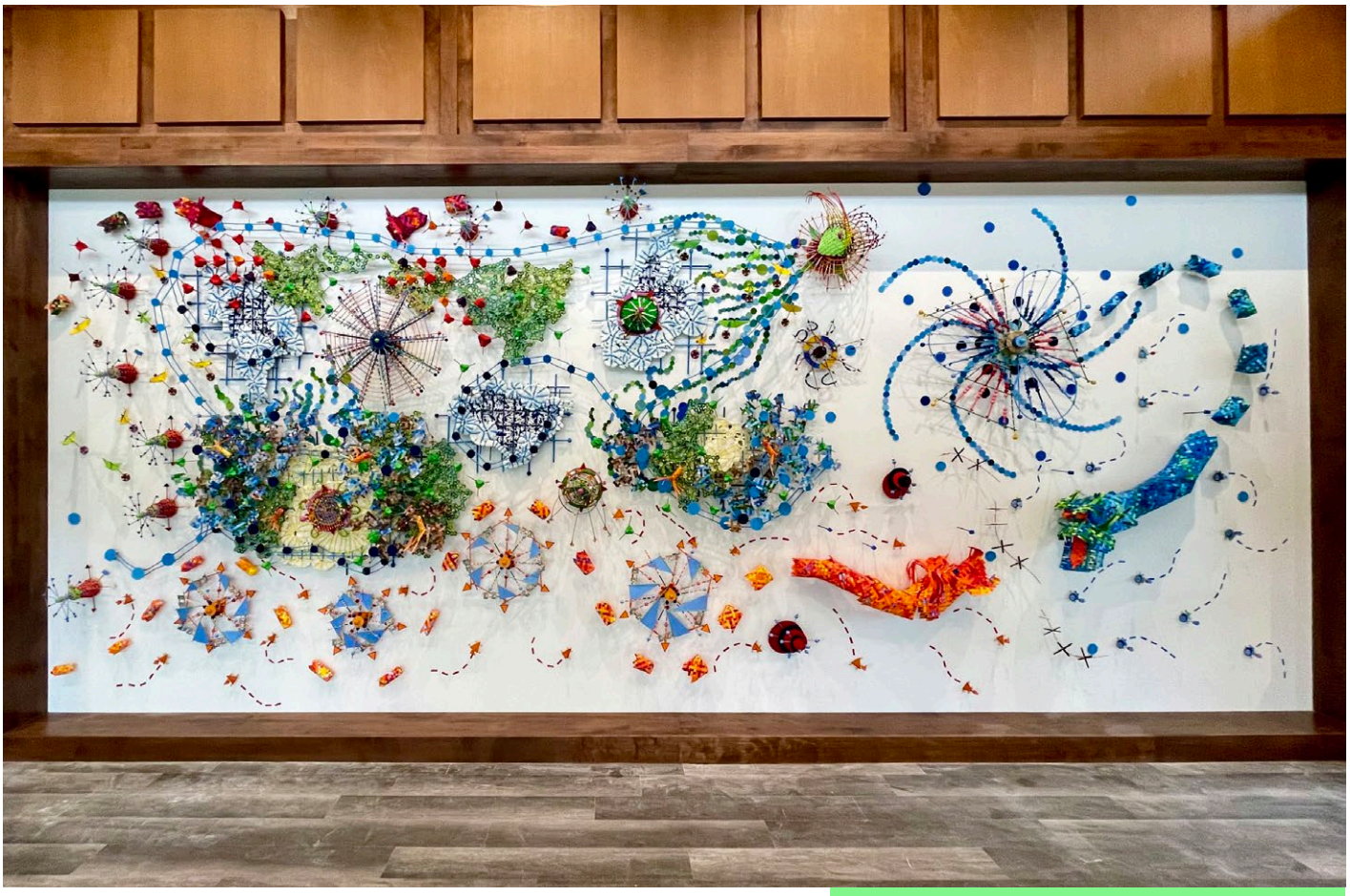


Fig. 3. *"Changing Waters"* by Nathalie Miebach (Miebach, 2022). The artwork consists of a large wall piece and 4 woven pillars that examine the Gulf of Maine's biological, geophysical, and seasonal transformations through the lens of weather and buoy data.
All image rights are with Nathalie Miebach.

Data Mapping

Data are often formal representations without immediate aesthetic form, such as raw data that are numerical, table-based, coded or symbolic. A data artist generates a translation that maps the formal data properties onto specific artistic parameters such as colour, positions on a canvas, or notes of a musical scale. There are numerical datasets that suggest a mapping: the latitude and longitude values of a bird's location over time could be mapped to the x- and y-coordinates of a canvas. The speed of the Earth spinning could correlate with the speed of an animation. In these examples, we map certain properties from the world's space (the location of a bird, the speed of the Earth's turning) onto the space of the artwork (the location on the canvas, the speed of the animation), while the underlying data type (location, speed) remains unchanged. Beyond these straightforward data mappings, many data artworks present a more complex relationship to the underlying data that can be challenging for the audience to decipher. Similarly, artists face the challenge of interpreting formal data creatively while maintaining a meaningful connection to the formal data, ensuring their work does not appear arbitrary.

Consider Nathalie Miebach's "Changing Waters" (Miebach, 2022): a sculpture that was created through an artistic translation of weather and buoy data of the Gulf of Maine (Fig. 3). Here, the mapping of data

to sculpture is not immediately apparent. The sculpture creates an appealing tension between its real-world data source and its abstract representation. The abstraction consists of shapes and colours that allow for some form of recognition of what we know about weather and oceans. This phenomenon is similarly found in traditional abstract art that transforms its subjects into non-representational forms. The abstraction in data art often highlights the disconnect between data and human perception. While we learn through experience to interpret some everyday numbers, like relating forecast temperatures to physical comfort, we typically lack intuition for understanding formal data beyond these familiar contexts. While one might question whether Miebach's artwork strays too far from its source data for meaningful representation, this criticism overlooks how humans also struggle to comprehend raw data directly. The artistic interpretation may convey insights more effectively to non-experts. Datamorphism includes and describes this tension between a data artwork's abstract aesthetic, the data and the concrete phenomena the data represents.

The interplay between dataset size, meta-communication, data types and mapping reveals complexities extending beyond common definitions of data art. The novel concept of datamorphism comprehensively captures these multifaceted relationships between data, artistic representation and its perception.

4.2. Exemplary Datamorphism in "The Lake" by Julie Freeman

As an example of datamorphism, we analyse Julie Freeman's artwork *"The Lake"* (2005) (Freeman 2018), as shown in Fig. 4. *"The Lake"* is based on data from the other-than-human, which in this specific case refers to fish.

For this artwork, Julie Freeman utilised real-time data from tracking sixteen fish in a lake for six weeks to create an abstract animation and soundscape. The work was installed in a cylindrical tower measuring 9 meters in height, creating an immersive audiovisual environment for viewers positioned in the tower below. Each fish was assigned a set of seven environmental sound samples, recorded from underwater and lakeside locations. The sound samples were triggered and modulated based on the fish's location, position, speed, and direction. For instance, if a fish's speed changed significantly, the corresponding sound sample's rate was adjusted. The interactions between the fish, whether in proximity to others or isolated, also influenced the music, creating a "complex emergent soundscape" coupled with visual effects.

The dataset size (sixteen fish), while not so large as to be perceived as referring to some "truth," goes beyond what is consistently ob-

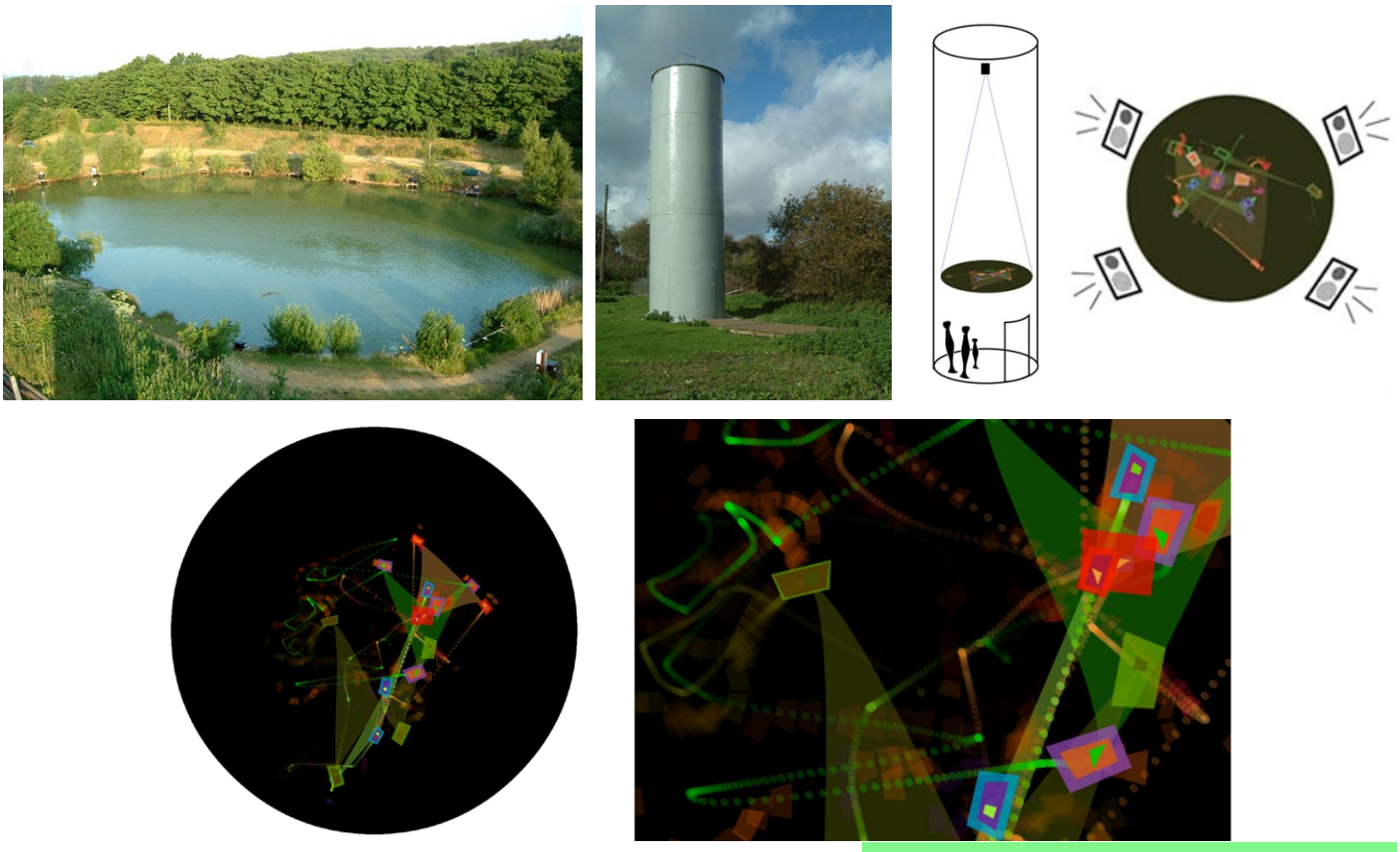


Fig. 4. *"The Lake"* by Julie Freeman (Freeman 2005). The artwork is a site-specific installation (presented in the cylindrical silo next to the pond, seen in the top row, middle image) and pioneering example of data art that incorporates live biological data in real time. It exemplifies datamophism by examining data's role in abstracting the other-than-human (in this case, fishes in the pond, seen in the top row, left image), their artistic representation (images in the bottom row) and our understanding of it.
All image rights are with Julia Freeman; images are used with permission.

servable by an individual. If just one fish leaves the viewer's field of view, an observation by the viewer's eyes becomes unattainable. The data collected on the fish's "location, position, speed, and direction [...]" constructs a specific and accurate representation that differs from what we can perceive. The potential to detect and project onto patterns and irregularities emerges, visualising what otherwise might have remained invisible, creating datamorphism. However, the used movement data are data of the perceptible rather than data of the non-perceptible. While we cannot readily observe a precise numerical representation of the movements of the fish, we can observe fish from our unmediated human perspective. The artwork consists of an abstracted audiovisual portrayal of the fish. Short of empirical evidence, we can only speculate how an audience might perceive the artwork and its data source. As the artwork was viewed near the pond the fish inhabited, trust in the data's authenticity seems likely.

Julie Freeman created *"The Lake"* through a datamorphic lens. Rather than, for example, interpreting a common anthropomorphic hero's journey of a fish, Freeman constructs a framework wherein the natural behaviour of fish becomes artistically expressive. The artist's approach avoids anthropomorphising the fish, instead allowing their movements and behaviours to emerge through the data translation process. The resulting representation derives directly from the captured data and, with that, from the fish, rather than solely from imposed human interpretations.

5. Discussion & Future Work

We introduce the concept of datamorphism to enhance understanding of how certain data properties, their relationships, and our knowledge of data shape both the form and reception of a given data artwork, as well as the other-than-human phenomena represented in it. We are inspired by the definition and mechanisms of anthropomorphism when developing datamorphism. While datamorphism shares some characteristics with anthropomorphism, the two concepts are fundamentally distinct. However, they do not necessarily exclude each other. Our discussions throughout the text may appear critical of anthropomorphism; yet, viewing it solely as positive or negative is overly simplistic. One can argue that attributing human traits can cultivate empathy, solidarity with the other-than-human, and a sense of connectedness. In this research, however, we strive for a change of perspective, seeking new ideas to foster solidarity and understanding of the other-than-human. We do so through a post-humanist lens, recognising the agency and presence of the other-than-human that transcend the constraints of an anthropocentric view. Currently, we are not aware of any systematic evaluation comparing the effects on perception of anthropomorphic representations and representations that carefully avoid a human-centred approach. Furthermore, rejecting our human perspective is neither possible nor inherently desirable. Similarly, the notion of truly objective data is ultimately illusory. Our interpretations are inevitably shaped by our human experience. Nevertheless, there is value in deliberately expanding our understanding and consciously attempting to reduce the human perspective to challenge our innate biases and reveal aspects of reality we might otherwise overlook.

While existing research on data art explores many of the aspects we discuss, datamorphism offers a comprehensive framework that uniquely addresses the complex interrelationships between data, artistic expression, and audience perception, while also acknowledging the intuitive and affective characteristics. However, our definition of datamorphism requires further theoretical contextualisation, refinement and expansion. Conducting studies centred around audience receptions of data art could help identify common patterns in interpretation and test how helpful the current definition of datamorphism is for understanding the ontology of data art. Qualitative interviews with artists about their data art practice might help in understanding how data shape artists' perspectives on the phenomena they engage with. Analysing the existing discourse around data in art contexts would provide further insight into the multitude of perspectives that artists take on this rapidly evolving art material.

Datamorphism, grounded in theory, emerges in practical data art explorations. We hope the analogy to anthropomorphism, a prominent and practical concept in art of the other-than-human, inspires and supports artistic engagements with data of the other-than-human. This form of artistic datamorphic work may begin with an exploration of the data types mentioned in Section 4.1.

Overall, our work establishes the foundation for datamorphism, opening new pathways for theoretical and practical development alike.

6. Conclusion

How societies apprehend and ascribe value to the other-than-human is in constant flux. Our views are shaped by politics, cultural practices, including art, and scientific consensus. Digital data have risen to prominence in modern society and play a significant role in how we navigate the world. Projects such as the Max-Planck-Institute's initiative "ICARUS" or Google and NOAA's use of AI to help decipher whale communication (Allen et al. 2024) demonstrate the potential for data-driven methodologies in studying other-than-humans. Artists have also turned their attention to this development and use data in their art practices. Agreeing with "the nonhuman turn" (Grusin 2015), artworks have been created that centre the other-than-human, by artistically engaging with data collected from them. Questioning data's perceived authority and implicit claims to objective truth, we examine how this particular art material might influence both artists' and audiences' perspectives, as well as the aesthetics of data artworks concerned with the other-than-human. Datamorphism, inspired by anthropomorphism, helps describe how data, their cultural perception and one's individual understanding thereof, open up new ways of perceiving other-than-human beings and phenomena in data artworks. We hope that datamorphism will aid scholars and artists in describing and thinking about data art's potential for novel perspectives on the other-than-human world.

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Insidious Imaginaries: A Critical Overview of AI Speculations

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Speculative thinking about the capabilities and implications of artificial intelligence (AI) influences computer science research, drives AI industry practices, feeds academic studies of existential hazards, and stirs a global political debate. It primarily concerns predictions about the possibilities, benefits, and risks of reaching artificial general intelligence, artificial superintelligence, and technological singularity. It permeates technophilic philosophies and social movements, fuels the corporate and pundit rhetoric, and remains a potent source of inspiration for the media, popular culture, and arts. However, speculative AI is not just a discursive matter. Steeped in vagueness and brimming with unfounded assertions, manipulative claims, and extreme futuristic scenarios, it often has wide-reaching practical consequences. This paper offers a critical overview of AI speculations. In three central sections, it traces the intertwined sway of science fiction, religiosity, intellectual charlatanism, dubious academic research, suspicious entrepreneurship, and ominous sociopolitical worldviews that make AI speculations troublesome and sometimes harmful. The focus is on the field of existential risk studies and the effective altruism movement, whose ideological flux of techno-utopianism, longtermism, and transhumanism aligns with the power struggles in the AI industry to emblematize speculative AI's conceptual, methodological, ethical, and social issues. The following discussion traverses these issues within a wider context to inform the closing summary of suggestions for a more comprehensive appraisal, practical handling, and further study of the potentially impactful AI imaginaries.

1. Introduction

Artificial intelligence (AI) researchers and scientists have tended to make strong claims and bold predictions since their field's early days (see Mitchell 2019a, 19–21; Natale 2021, 33–49). This tendency is fuelled by the fuzziness of core theoretical assumptions (The Royal Society 2018) and by the worldviews of stakeholders acting in an exploratory domain replete with unknowns. It is also driven by opportunistic temptations to exploit the economic and sociopolitical turmoil around AI. Abiding by the entrepreneurial slogan "fake it 'till

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you make it" and leveraging the cultural legacy of science fiction, the information technology and AI industries have established a thriving culture of overstating and overpromising in which speculations about AI's current, emerging, and future capabilities and consequences play a prominent part (Lorusso 2019, 64–77; Katz 2020).

Speculation is a process of conceptualizing beyond the factual. It combines imagination with the creative extrapolation of the available knowledge to predictively theorize about certain subjects (Nguyen 2021, 139). The main subjects of AI speculations are the possibilities for, and the entailing benefits and risks of, creating artificial general intelligence (AGI), developing artificial superintelligence (ASI), and reaching technological singularity. The vagueness of these concepts opens the space for unfounded claims and futuristic scenarios whose tones range from cataclysmic alarmism to deistic techno-utopianism.

The increasing application scope of AI technologies endows AI speculations with an apparition of relevance and urgency, humanity's intelligence chauvinism gives them an aura of profundity, and our love-hate relationship with technoscience supplies the emotional charge. Corporate-leaning institutes that investigate AI-related hazards aid the AI industry in proliferating the speculative AI discourse, while eager media coverage expands its reach and boosts it with sensationalism. As a result, AI has superseded nuclear technology, biotechnology, and genetics as the forefront technoscientific topic of political debates and remains among the primary sources of inspiration for films, novels, computer games, and other forms of popular culture (Marcus and Davis 2019; Mitchell 2019a 45, 215–229; 2019b).

In this paper, I draw a critical outline of speculative AI. In three central sections (2, 3, and 4), I navigate the web that interconnects AI speculations with science fiction, spiritual longings, charlatanism, dubious academic projects, questionable interests, and problematic sociopolitical worldviews. My focus (in section 4) is on the field of existential risk studies and the effective altruism movement, whose scholarly and activist work frequently fuses the AI-related phantasmagoria and mental gymnastics which support the Weltanschauung and aspirations of the tech industry, with potentially wide-reaching fallouts. Existential risk studies and effective altruism are not monolithic, and I reference authors who cast divergent critical views on their concepts, methodologies, and ethics. Nevertheless, the dominant narratives in existential risk studies and the prevailing practices of effective altruism encapsulate the interplay between philosophical pondering, techno-utopian fantasies, corporate interests, and cyberlibertarian ideologies, which constitute the AI regime. In the

discussion (section 5), I juxtapose the main issues of this interplay into a wider critical perspective for understanding AI speculations. In conclusion (section 6), I make suggestions for a more comprehensive appraisal and practical handling of the possibly impactful AI imaginaries. Constructing a sound framework for these tasks is a matter of future work, and my goal with this paper is to provide a critical map that contributes to its foundation. That critical map may also be conducive to studying speculative AI in and beyond the specialist academic and techno-scientific sectors, as well as to the more exhaustive examination of the relationship between AI speculations and practices in AI art and other areas of cultural production.

2. AI and Science Fiction

As an important factor in romanticizing scientific research and technological development, science fiction also catalyses the penchant for AI speculations in the computer science and tech communities:

> Science fiction as a genre emerged in the era of modernity with its social upheavals and belief in technological progress. Basically, science fiction tells stories about and through fictional technology, but within the prevailing paradigm of scientific thought. Thus, the departure point of science fiction is a fictional but scientifically explainable novelty, a "novum", which establishes a new world different from the one we know. The scientific foundation, however, does not imply that the novum must be able to truly exist in the real world, but that it is cognitively imaginable within the story world. In this way, the novum enables "what if"–questions to speculate about the present and alternative futures in various, but cognitively plausible constellations. (Hermann 2021, 3)

The novum of AI has a long history in science fiction. It usually serves as a figurative, metaphorical, or allegorical device, but frequently regresses into a stereotype or cliché with a heavy anthropocentric baggage that exposes human exceptionalism (see Tromble 2020, 5).[1] The flow between science fiction and technoscience is bidirectional, so the fantasies of Arthur C. Clarke, Isaac Asimov, Ursula K. Le Guin, Philip K. Dick, William Gibson, Neal Stephenson, and many other authors have been important sources of inspiration and ideas for several generations of scientists and engineers. The influence is so strong that some college courses have been devised to employ science fiction as an effective entry point for teaching AI and computer science (Tambe et al. 2008; Burton et al. 2015). However, science fiction's

inspirational appeal can also limit creative and critical thinking by "sweetening" or canonizing certain concepts regardless of their validity and instead of alternative ideas, and by stimulating aspirations that may ultimately prove meaningless or dangerous.

As a prominent subgenre, the science-fictional AI has become a reference point in a larger corpus of speculative discourse on AI's technical features, risks, and ethics (Broussard 2018; Schmitt 2021). If taken with critical caution and reserve, science-fictional AI may provide metaphors for technoscientific or philosophical thought experiments about the human condition and sociopolitical issues, but not for valid foresights or technology assessments because it is, first and foremost, a dramatic fiction tailored for popular consumption (Giuliano 2020; Hermann 2021). Like traditional narrative forms, science fiction reflects and reinforces our dispositions and behavioural tendencies with all their flaws and constraints. This may be valuable as entertainment and purposeful as a creative driver, but is insufficient for discovering new ways of thinking and knowing (Kay 1995).

A related problem of science-fictional inspiration stems from the genre's hyperproduction and acutely uneven artistic strength; there is an apparent mismatch between the popularity of science fiction works and their stylistic accomplishments, psychological inquests, or philosophical insights (see Kornbluth 1957, and Sontag 2017). The prose of many renowned science fiction authors tends to be pretentious, intellectually vacuous, operatic, verbose, self-indulgent, turgid, technophilic, gimmicky, kitschy, or schlocky (Ra 2022; Casella Brookins 2023). Regardless of its artistic merits, science fiction is criticizable as a tacit ideological platform that coerces youthful imagination and makes it productive by conjuring up enjoyable narratives about fantastic technological accomplishments and fictional worlds, which motivate young consumers to actualize them as adults (Nguyen 2021, 127–165).

Furthermore, the common affinity among scientists and engineers for science fiction's nerdy, Borgesian armchair-type adventurism may signal the insensitivity to recognizing and appreciating the emotional wonders, intellectual challenges, creative motives, and relational nuances in the real world (Kelion 2013). The capacity for this kind of recognition and appreciation is one of the contributing factors to psychological maturity and social responsibility, which are chronically iffy in the computer science and tech industry communities (Grba 2024, 13–14, 16; see also Dayan 2017; Wayne Meade et al. 2018; Jacoby 2020; and Marx 2023).

3. AI "Metaphysics"

The imaginaries of AGI, ASI, and technological singularity that permeate science fiction in various contexts (Hrotic 2014) also serve as devices for entertaining infantile fantasies of omnipotence and immortality, mythologizing, magical thinking, and religiosity.[2] Their allure has merged with the extrapolations of computer technologies' processing volume and speed, and the socioeconomic momentum of applied AI to constitute an important "metaphysical" layer of speculative AI.

The variety of definitions of AGI (also called human-level or strong AI) reflects the lack of robust, consensual understanding of intelligence and the closely related but even more elusive concept of consciousness in AI research (Mitchell 2019a, 42). Their baseline does not exclusively refer to human intelligence but to the artificial systems' capability for solving different problems without being trained with domain-specific data (Loukides and Lorica 2016; Sublime 2024, 42). However, AGI is commonly understood as a type of AI that matches or surpasses human problem-solving capacities, reasoning, learning, planning, and creativity across a wide range of tasks or domains (Leffer 2024).[3]

This notion accords with the computational theory of the mind (computationalism), which proposes that the mind is a computer and that mental processes are essentially computational. Influenced by Alan Turing's separation of the mind from material reality (1950), which continues the tradition of mind/body dualism reaching back at least to Descartes,[4] computationalism adopts the notion of intelligence as an unembodied mathematical construct that "operates" physical entities. It posits that the principles of universal Turing machine computation allow us to capture the essence of human thought in practice and all thought in principle, which implies that a computer programmed to reproduce human cognitive functions should be deemed intelligent (see Dietrich 1990; Browne and Swift 2019, 3; Rescorla 2020; and Natale 2021, 36). Computationalism is popular among AI scientists and some philosophers but faces strong opposing views and evidence about intelligence and consciousness as evolved biological phenomena, not substrate-independent information processors (see Damasio 1994; Steels and Kaplan 1999; Koch 2018 and 2019; Mitchell 2019b, 7; and Seth 2021).

The idea of computers that emulate human problem-solving and learning abilities often fallaciously implies their increased autonomy, leading to speculations that generally intelligent systems would

quickly become superintelligent (see McQuillan 2022, 89). They would absorb the totality of human knowledge through the available learning data and combine their speed with reasoning mechanisms to make discoveries that would further increase their cognitive capacities and allow them to greatly surpass humans in all intelligence-related areas, such as scientific creativity, general wisdom, and social skills.[5] Such speculations frequently assume that generally intelligent computers will be capable of uninhibited self-improvement (both algorithmic and material), ultimately leading to the hyper-mental power and functionality of ASI, with either utopian or dystopian consequences.

The concept of runaway AI threads from computer scientist John von Neumann, who had considered but ultimately rejected it in the mid-1940s (Shanahan 2015, 233; Larson 2021, 36). Two decades later, Alan Turing's Bletchley Park fellow code-breaker Jack Good formulated the intelligence explosion model of self-improving AI that would lead to "ultraintelligence" (Larson 2021, 33–35). By the late 1980s, computer scientist Raymond Kurzweil, robotics pioneer Hans Moravec, and computer scientist/science fiction author Vernor Vinge extended these concepts into the eschatological vision of technological singularity (Vinge 1993; Kurzweil 2005; Shanahan 2015; Irrgang 2020; Larson 2021, 44–49).

Technological singularity is a hypothetical historical point at which the cumulative progress in computation, nanotechnology, genetic engineering, and other areas of science and technology will accelerate to such an extent that biological (human) and machine intelligence will merge in an exponential and irreversible but benevolent co-evolution (Mitchell 2019a, 45–50). Fusing religion with technophilia, singularity is one of the tenets of transhumanism (discussed in section 4.1) and is often derisively called "the rapture of the geeks" (Giuliano 2020, 8). However, singularitarian assumptions that the constraints of material existence can be transcended by using material technology are unsubstantiated and the beliefs that the corporate tech sector would share or renounce its accrued privileges for the benefit of all humanity look suspicious in the light of its wasteful, exploitative, and oligarchic reality (Lorusso 2019, 21–25; McQuillan 2022; Rushkoff 2022).

4. AI and Existential Risk Studies

Many speculations about advanced AI revolve around scenarios that connect it with existential imperilment. They figure prominently in the field of existential risk studies, which combines an offshoot of

analytic philosophy, utilitarian ethics, quantification, statistical risk analysis, and imaginative thinking to explore extinction threats to humanity or all life on Earth.[6] Existential risk studies gained institutional prominence, caught public attention, and attracted the tech sector's financial backing in the first two decades of the twenty-first century. Against strong expert disagreement about the empirical basis for considering AI as an existential risk, the scholars in this field favour contemplating AI dangers over calamities that abound in factual data (Cremer and Kemp 2021, 14–15).

A prominent variety of existential risk speculations is about collateral damage that a hypothetical super-optimizer algorithm with extensive control over the material world may cause, running inconsiderately of human goals and values. Its key point is that the further development of statistical machine learning could make AI systems hard or impossible to control, not because of their intrinsic will to power but because of their simplistic reasoning mechanisms. For example, Stuart Russell's book *Human Compatible* (2019) is based primarily on extrapolating the efficiency of AI programs that optimize for fixed human-defined objectives. It suggests that, if future AI systems get "too smart too quickly", their alignment with human interests will be compromised. This concern plausibly implies that engineers may irreversibly entrust powerful AI systems with critical tasks despite their lack of commensurately strong control mechanisms such as human-level generalization and common-sense reasoning (Mitchell 2019b, 7), but also assumes that human interests are universal, neutral, and conflict-free. It is thus not surprising that Russell does not acknowledge the actual mandating trend, as absurdly reckless as the fictional one in his book, which already underpins the widespread deployment of inherently flawed and harmful AI systems (see McQuillan 2022, 27–71).

Devising a robust, broadly acceptable ethical framework is a major challenge for AI value alignment. It requires a precise, stable, and consensual common ground to build "universal" ethics for humanity. However, this necessary groundwork approach to ethics is attenuated or excised in the mainstream AI discourse mainly because of political infeasibility and technical intractability. Instead, the tech community nurtures a tacit presumption that historically, culturally, and socially divergent human interests, goals, and values are compatible and homogenous and thus can be neatly harmonized as straightforward ethical rules (see Dougherty 2001; McQuillan 2022, 35; Grba 2023; McFadden and Alvarez 2024). For instance, Max Tegmark's AI speculations in the book *Life 3.0* (2017) are remarkably pragmatic

in many respects but treat ethics selectively and superficially. Tegmark mentions some obstacles to implementing basic "kindergarten ethics" into future AI but never discusses their underpinnings in the biological and historical heritage of human competitiveness or the political, economic, and cultural factors of conflicted human goals (Tegmark 2017, 283–288). He admits that interdisciplinary conversation about AI ethics is necessary because human interests and goals are not universally aligned (293) but avoids explicating that this would entail addressing present (not science-fictional) power differentials and social inequities (12–28).

A related variety of existential risk scenarios presumes that any intelligent actor will inevitably tend to dominate and exploit, based on the premise that natural selection shaped humans and other animals to use intelligence for dominance and exploitation. For example, in his book *Superintelligence* (2014), Swedish-born analytic philosopher Niklas Boström (widely known as Nick Bostrom) leverages computationalist premises to speculate about the pathways and consequences of self-modifying ASI.[7] As mentioned in section 3, the viability of computationally emulating (human) intelligence is unknown, so Bostrom's superintelligence remains a mere assumption which, like his several other works, exploits arbitrariness. There is no reason to believe that a software designed to pursue a predefined goal by optimizing some of its functions would be able to autonomously (without human input) define the concept of domination and set it as the ultimate purpose. Although Bostrom describes how an already superintelligent software might elaborate a strategy to overtake the world, he does not explain how this superintelligence would emerge in the first place. He takes the possibility of superintelligence as "obviously plausible" and therefore not requiring further explanation. By pitting human and machine intelligence in game-theoretic models of optimizing objectives, Bostrom's and Russell's thought experiments severely restrict the abilities of human cognition (Larson 2021, 34–35, 83, 279). One of the main reasons for the conceptual unevenness and ethical flimsiness in these and other AI speculations is their techno-utopian slant.

4.1. The Techno-utopian Complex

Bostrom's essay *Existential Risks* (2002) was one of the early works that intersected analytic and utilitarian philosophy with largely abstract extinction scenarios (Schuster and Woods 2021, 5–6). It defines existential risk as a failure to attain technological maturity (by plateauing, stagnation, or regression) or a failure to spread beyond Earth, which prevents humanity from reaching a "desirable future" and fulfilling its "long-term potential". These two types of failure

may have any cause, so the definition essentially equates pressing or plausible near-term calamities, such as nuclear holocaust, with more distant hypothetical futures where humans attain sustainability and equitability but without major technological progress. Notably, Bostrom nominally identifies the subject of his existential concern as the "Earth-originating intelligent life" but favours the progressive technological enhancement of human physiological and mental capabilities (especially intelligence) toward a transhuman condition as requisite for survival and therefore a moral and ontological imperative (Schuster and Woods 2021, 16). This, and later Bostrom's publications on existential risk, drew praise in the tech community and some academic circles and were instrumental in establishing the field of existential risk studies.[8]

During the last two decades, Bostrom's philosophizing about far-off transformative technological changes, replete with science-fictional tropes and restrictive championing of intelligence, has both informed and reflected the techno-utopian approach which dominates the theorization and advisement in existential risk studies (Cremer and Kemp 2021, 3 and passim; Schuster and Woods 2021, 6–8, 23–43). The techno-utopian complex clusters mutually reinforcing notions, ideas, and attitudes in three complementary belief systems: transhumanism, total utilitarianism, and strong longtermism.

Transhumanism is a movement based on the belief that it is worth exploring the technological modifications of life, which include augmented humans, cyborgs, androids, and digital simulants. It primarily seeks to hack human biological mechanisms to extend life, expand cognition, increase welfare, and enhance well-being. Transhumanists believe that, depending on continued progress in science and technology, these improvements would synergize and become exponential in scale and speed, which would lead to achieving immortality, superintelligence, and a greater capacity for pleasure (see Pilsch 2017; and Farman 2020). Although purpose, virtue, love, and justice are not central values in their utopia of "surpassing bliss and delight" (Bostrom 2008), transhumanists argue that fictional posthuman lives are more valuable than existing humans' lives because they would be much longer, richer, and marked by more "net positive experiences". Thus, from a transhumanist perspective, efforts at addressing existential risks are not primarily about preventing the suffering and passing of presently living humans but focus on preserving the human species so it could technologically enhance itself into a posthuman one, which would be the real beneficiary (Cremer and Kemp 2021, 4–5; Schuster and Woods 2021, 23–43).

This perspective follows utilitarian reasoning, where ethical choices are driven by the so-called "expected value" (discussed in section 4.2) and the notion that potential future lives are morally equivalent to existing ones. Total utilitarianism defines moral rightness as the maximization of well-being regardless of space and time and argues for (or bets on) the future as an overwhelming moral priority, based on an assumption that the number of future lives could be unimaginably large. It is closely related to strong longtermism, which emphasizes the ethical imperative of making the choices expected to have the best effect in the distant future (Greaves and MacAskill 2001). Unlike other schools of thought that focus on evident or probable long-term issues, strong longtermism is concerned with pursuing high payoffs thousands or millions of years in the future. Exceptionally valuable potential gains justify gambling with extremely low probabilities for their actualization (see MacAskill 2019; 2022b; Centre for Effective Altruism 2024). Common in all these views is the premise about far larger populations of technologically enhanced or simulated and thus happier/better beings in the deep future.[9]

Although techno-utopian conceptual underpinnings and methodologies are neither exhaustive nor exclusive for understanding the human condition and extinction risks (Schuster and Woods 2021, 18), they have a noticeable media presence and influence a range of circuits in and beyond academia. They partly motivated the establishment of the effective altruism movement and have largely informed its practices. Effective altruism "advocates the use of evidence and reason for impartially selecting causes and calculating benefits to mobilize intellectual and material resources that provide the greatest good" (Effective Altruism 2023). This definition does not necessarily require long-term speculations, and effective altruism was initially concerned with current global problems, such as health and poverty, and helped improve the standards for organizing and evaluating charitable projects. Over time, however, the rising emphasis on humanity's long-term future within the movement turned many effective altruists into longtermists (Samuel 2022).

The lively ideological resonance of transhumanism, total utilitarianism, and strong longtermism with the Silicon Valley worldviews has gained existential risk studies and effective altruism widespread popularity among the AI safety research communities and ample financial support from tech entrepreneurs.[10] This has turned Bostrom and some other existential risk thinkers and effective altruists into major public figures and won them consulting positions with AI companies and governmental advisory bodies where their

expertise contributes to decisions, policies, and strategies that may affect wide swaths of society.

4.2. Tainted Conceits

Existential risk scholars and effective altruists claim to strive toward scientific objectivity, but the prevailing techno-utopian inclinations introduce theoretical and practical problems in these fields. Their key issues are the ambiguous but morally loaded definitions of central terms, arbitrary categorization and incoherent assessment of future risks, non-representative ethical views, overreliance on assumptions and speculations, precipitation of certain calamities by researching them, and dangerous mitigation strategies.

Bostrom's treatment of central terms, such as "expected value", "technological maturity", "desirable future", and "humanity's long-term potential", in his discussion of existential risk (summarized in section 4.1) exemplifies the abstractness, ambiguity, subjectiveness, and ideological sway of the techno-utopian approach in existential risk studies and effective altruism. Expected value is the product of multiplying a certain outcome's value by the probability of its fulfilment. This concept may be useful in a range of theoretical contexts, but difficult to apply rigorously to the areas of deep uncertainty (with low information about probabilities) such as existential risks (Cremer and Kemp 2021, 5–6). Crucially, evaluating expected value requires a particular notion of value, which opens the gates for biased intuitions and preferences. Two other key concepts—technological maturity and humanity's long-term potential—are the ultimate unknowns. Existential risk or well-being does not need to be tied to technological maturity, and it is doubtful that scholars can reliably predict hazardous or beneficial factors of future technologies. Different plausibly desirable futures often involve conflicting trade-offs, and neither existential risk thinkers nor anyone else can define them with ultimate authority. Similarly, neat techno-utopian distinctions between existential and global catastrophic risks presume firm systemic knowledge about the functioning of society and many other complex systems on Earth, which we do not have.[11]

The community of existential risk studies is noticeably homogenous regarding income, class, ideology, age, ethnicity, gender, nationality, religion, and professional background. Most scholars are white males from wealthy Western countries working in well-endowed universities and foundations (Cremer and Kemp 2021, 8, 26). Similarly, effective altruism, longtermism, and transhumanism are most popular among the members of privileged and prosperous social groups.[12]

Their combined practices have cultivated a noticeable lack of attention for references, voices, and participants from marginalized groups and colonized societies that face oppressive and perilous conditions hic et nunc (Schuster and Woods 2021, 8–9, 20). Instead, they favour unabated technological progress as vital for achieving existential security and wellbeing, and—while recognizing the risks of some technological development paths—pay less attention to changing their political or economic drivers. They often advocate the idea of differential development toward beneficial and protective technologies, such as aligned AGI, but dismiss various options to regress, relinquish, or stop the development of certain technologies as infeasible or impossible (Cremer and Kemp 2021, 17).

Another indicative partiality is that none of the prominent existential risk thinkers discuss their field's key term "existence" with the reference to existential philosophy (existentialism), which emerged as a response to existential threats in the first half of the twentieth century: social inequalities, racism, imperialism, world wars, genocides, nuclear arms race, biodiversity depletion, etc. (Crowell 2023). Existentialism provides a more robust basis for understanding existential risks because it accommodates a range of embodied affects, lived experiences, and material and ecological relations that are not reducible to the concepts of intelligence, probabilistic reasoning, and utilitarian calculations (see Schuster and Woods 2021, 12–14). It calls for understanding and taking responsibility for one's being in the real world instead of fantasizing about immortality or omnipotence. These principles do not sit well with the techno-utopian ethos.

In contrast to existential risk scholars' assertions about striving to develop plausible scenarios grounded in scientific knowledge, their speculations are often insufficiently conclusive for making sound predictions and recommendations. They are saturated with imaginaries that frequently look superficial, particularly for ignoring the principal limits of computation and material constraints,[13] while fancying continued technological progress toward blissful transhumans in interstellar settlements or simulated realities and glossing over the violence and other unwanted side effects of (failed or successful) efforts to achieve such utopias.

All these issues have prompted scholars in humanities, science and technology studies, and some existentialist risk thinkers to criticize the lack of intellectual rigor and moral credibility in existential risk studies. They emphasize the field's radical mismatch between method and object of study, view its reliance on de facto unpredictability as pseudoscientific, and deem its social unrepresentativeness

undemocratic and ethically tenuous (Cremer and Kemp 2021, 6–8, 17–18; Schuster and Woods 2021, 45; Gebru 2022; Samuel 2022; Torres 2023; Anthony 2024).[14] Bostrom has been at the centre of this critique as the field's originator and most recognizable influencer. Some philosophers and scientists dismiss his ideas as inherently unscientific or religious because they deal with imaginary and unprecedented subjects that are usually impossible to describe sufficiently or discuss rationally. For instance, Massimo Pigliucci argues (2021) that Bostrom uses hypothetical technoscientific challenges as a pretext to reboot the so-called "analytic metaphysics" or "first philosophy", which has been replaced by science for several centuries.[15] Furthermore, practical remedies that Bostrom and other existential risk thinkers propose for hypothetical calamities usually endorse techno-solutionist and totalitarian ideas that inform or reinforce troublesome political views and ethically questionable enterprises in the tech sector.

4.3. Present Dangers

Problems of existential risk studies and effective altruism are not purely theoretical or relevant only within academia. Even though their stakeholders belong to narrow demographics and champion relatively obscure belief systems, the ideological alignment with the tech industry has attracted economic and political support for their academic establishment and placement in the corporate and government advisory bodies. In such a position, their conceptual shortcomings, methodological flaws, and biased worldviews can precipitate catastrophes by missing certain existentially risky pathways, wasting resources on incorrect speculations, and fantasizing dangerous mitigation solutions (Cramer and Kemp 2021, 20–25). The practices of existential risk and effective altruism communities have stirred controversies and materialized some of their critics' key warnings.

The case of Bostrom's paper "Vulnerable World Hypothesis" (2019a) illustrates how speculation-based recommendations for avoiding calamities can contribute to the catastrophes they intend to escape. This paper posits that certain emerging ideas may initiate or influence technological development which may become hazardous to human civilization in the long run. Among several options to protect against them, Bostrom's comprehensive solution (including policy recommendations) proposes ubiquitous AI-governed surveillance and extreme policing. The surveillance system would involve the mandatory use of "freedom tag" devices whose multiple cameras and microphones continuously track citizens and provide their behavioural data to state-employed "freedom officers" mandated to

order pre-emptive strikes by drones or the police, all under the constant watch of AI that prevents misuse. Bostrom publicly discussed this AI restaging of Orwell's *1984* without irony, self-criticism, or distancing from the fact that such totalitarian measures may inspire or aid authoritarian and malicious actors (Bostrom 2019b; see also Cremer and Kemp 2021, 12, 20–26).

Although Bostrom restrains from openly advocating for the exploitative instrumentalization of the techno-utopian paradigm, he does not seem eager to criticize it, and he has developed a chronic propensity for self-assured flirting with problematic claims. For example, as a postgraduate student at the London School of Economics in 1996, he openly expressed racist views in an Extropians listserv email, where he used the N-word, arguing that white people were more intelligent than black people. In 2023, Bostrom issued an apology for this "incident" but conspicuously failed to withdraw his central contention about race and intelligence, and instead made a partial defence of eugenics (Torres 2023). As another example, Bostrom's concept of "dysgenic pressures" in *Existential Risks* (2002) reinvigorates the eugenicist idea from the 1920s and 1930s that "less intelligent" people might outbreed "more intelligent" (Torres 2023; Ciurria 2023; Anthony 2024).

Effective altruism shares many views with existential risk studies, and some of their most respected members express, promote, or tolerate racist, xenophobic, classist, and ableist attitudes (Torres 2023). Effective altruist projects that bring theory into practice often involve ethically dubious mechanisms, and some function as self-serving schemes. The movement's affinity for the cryptocurrency market, which has a proven history of criminality and impoverishment, gained infamy with the business enterprise of Sam Bankman-Fried. This vocal effective altruist was sentenced in 2024 to 25 years in prison for financial fraud and related crimes he committed running the Futures Exchange Trading company that operated a cryptocurrency exchange and crypto hedge fund between 2019 and 2022 (Anthony 2024; RationalWiki 2024b; 2024c). Bankman-Fried's fellow effective altruist entrepreneur Benjamin Delo trailblazed this modus operandi two years earlier by perpetrating money laundering at his crypto exchange BitMEX, for which he was sentenced in 2022 to a 30-month probation and payment of a ten million USD fine (Sinclair 2022).

Intentionally or coincidentally, these communities' fixation on AI-related risks also serves questionable interests in the AI industry. For instance, it is symptomatic how the leading AI companies often raise concerns about the existential dangers of AGI and call for AI re-

search non-proliferation. They frequently argue that we cannot be sure that all AI companies will be able or willing to build the aligned AGI, so only the prominent ones, with strong internal regulatory mechanisms, should be licensed to develop it (see World Science Festival 2024). Of course, big AI companies' work on advanced systems is largely secretive, which prevents meaningful external in-progress testing and oversight. The existential risk overtones in this rhetoric obscure the fact that AI engineers' explicit warnings about the absurdity and dangers of blindly building unsafe products should primarily bring into question their professional credibility and ethics, as well as their employers' motivations. Rather, it adds the aura of rationality to the frightening narratives that virtue-signal social conscience and secure support for the continuation of established AI business practices instead of critiquing and correcting them. It is part of manoeuvring toward an optimal combination of privileged position, opacity, and deregulation, which would grant top AI companies even more unaccountability and policymaking power than they already have, simultaneously increasing catastrophic risks (Narayanan and Kapoor 2024, 174).

5. Discussion

The fundamental obstacle to foretelling the attainment, risks, and benefits of AGI, ASI, and technological singularity is the lack of a precise and comprehensive definition of intelligence that we could use to reliably gauge the artificial intelligence "levels" and evaluate their robustness. Additionally, such breakthroughs would be unique events, so it is impossible to calibrate their predictions on comparisons with historical precedents.[16] These epistemic constraints undermine most AI speculations and AI-related existential risk studies and invalidate their policy-making legitimacy. As Melanie Mitchell pointed out (2019b): "Without more insight into the complex nature of intelligence, such speculations will remain in the realm of science fiction and cannot serve as a basis for AI policy in the real world". More generally, speculations cannot sufficiently account for the exponential complexity of the future because it unfolds through continuous interaction and coevolution of technology, economy, societal relations, and other intricate systems whose forecasting is inherently unreliable.[17]

Nevertheless, in corporate, academic, and pop-cultural discourses, the overarching claims about AI's present and phantasms about its future are usually more salient than cautious or sceptical views (see Larson 2021, 1–5, 41–42). Various motives and intentions, which include funding, promotion, marketing, and capitalization, drive some

AI researchers and pundits to attenuate informed criticality and articulate AI's perspectives in science-fictional terms while championing the existing pathways in AI science and industry as vital for mitigating or solving global-scale issues en route to an automated social utopia (Verdicchio 2023). For example, according to Demis Hassabis, a CEO and co-founder of DeepMind Technologies (a subsidiary of Alphabet Inc.), AI's world-transforming scope spans from biology and medicine (protein folding, drug development, discovering the origin of life on earth) through climate change and physics (solving nuclear fusion, finding the origin of the universe, understanding the nature of reality) to metaphysics (autonomous knowledge generation and innovation) (Hassabis 2024, see also McQuillan 2022, 100).[18]

Steeped in techno-solutionism,[19] such narratives use the verb "solve" to flatten difficult issues and implicitly subjugate them to the "AI magic", as in: "If we have an AI system that can help us understand mathematics, we can solve the economy of the world" (Hasani 2024). Facing AI's extant socioeconomic problems and other urgent global risks (nuclear weapons, pandemics, neoliberal economy, climate change), they come out as disingenuous or cynical. This is exemplified by the corporate AI sector's advertisement of its vital role in solving climate change based on "overlooking" significant natural resource extraction, pollution, and carbon emissions for building and running its own infrastructure. While selling products and expertise to the oil and gas industry for optimizing fossil fuel exploitation, AI companies refuse to disclose their own energy and material resources consumption. To groom a public image of sustainability and progressive environmentalism, they purchase carbon emissions credits (Dobbe and Whittaker 2019; Dryer 2021; McQuillan 2022, 23, 52).

The veneer of scientific rigor and rationality in existential risk studies of AI and related effective altruist projects serves sly business agendas and gives the tech industry an oft-undeserved aura of respectability and authority to claim its image of visionary entrepreneurship. It allows the techno-elites to consistently favour wondrous technological remedies for both far-fetched and present existential problems over concrete social or environmental initiatives (Schuster and Woods 2021, 6–7). Analogously, strong longtermism promotes universal values of stewardship (the duty of being a "good ancestor" for posterity) which hinge on the assumption that any hypothetical risk or gain, if we imagine it as existential, justifies any amount of expenditure (Fisher 2023).

The semantic open-endedness of speculative AI terminology also sets the stage for public intellectuals and science populists to gen-

erate seemingly profound but ultimately empty or meaningless narratives. For instance, here is how Joscha Bach, a Vice President of Research at the AI Foundation, opened his series of talks at the Chaos Communication Congress (Bach 2016): “Artificial Intelligence provides a conceptual framework to understand mind and universe in new ways, clearing the obstacles that hindered the progress of philosophy and psychology. Let us see how AI can help us to understand how our minds create the experience of a universe.” This is an overt mystification of a disciplinarily diverse field with many pathways, disputes, contradictions, and epistemological limits (see McQuillan 2022, 39–40). Another example is the bestselling physicist Michio Kaku, who frequently misrepresents his AI-infused scenarios about the utopian future as grounded in material sciences (see, for example, Kaku 2014 and 2018). On the fatalist side of the spectrum, historian Yuval Noah Harari prognosticates that even before AI “becomes sentient” large language models will usher the end of human-dominated history (pending extinction) because these models have “hacked the operating system of human civilization [language]” (Frontiers 2023, see also Narayanan 2023).

Speculative AI narratives usually rely on technocentric worldviews, abstractions, and oversimplifications to rewrite older ideas into grandiose visions (Larson 2021, 61–63). Since the links to provable facts, insights, and predictions that give plausibility to their central hypotheses are vague or too weak in comparison with the predictive mechanisms in science and engineering, yarns about the advent of ASI and technological singularity often have strong religious overtones that exploit human imagination, fears, and hopes. In these stories, we can usually replace the word “superintelligence” or “singularity” with “magic”, “miracle”, or “deity” without changing their meaning (Perry 2020).

6. Conclusion

High-profile AI speculations centre around the fundamental issues of human existence. Thus, their appraisal should not be concerned with entertainment values or intellectual aesthetics but with evaluating the usefulness in addressing these issues and with understanding other roles they may play. In this perspective, speculative AI has proved futile, counterproductive, or dangerous. Authors of popular AI speculations tend to abuse the fabulous and fascinating nature of imaginative thinking to promote and normalize corporate interests, evangelize techno-elitist worldviews, or spread meaningless fantasies. Many share cyberlibertarian ideas informed by the zeal for technologically mediated lifestyles and future visions steeped in libertar-

ian notions of freedom, social life, and economics (see Grba 2024, 15–16). They reinforce anthropocentric thinking, play along with the capitalist exploitation of AI, and champion egoistic aspirations for technocratic supremacy as the "astronomical" value.

Whether fuelled by futurism or science fiction, vacuous Gedankenexperiments or wishful thinking, tech-morality or religiosity, business or political ambitions, speculative AI is utterly frivolous but not harmless. The fancy, insincerity, hypocrisy, pretentiousness, or insidiousness lurking in magical AI thinking pollute our discursive, cognitive, economic, and political spaces already replete with undisputable problems (including the AI industry) that require immediate attention (see McQuillan 2024, 47–71, 54–57; Sublime 2024). Taking hypothetical predictions and unfounded claims uncritically, we risk allowing them to become pre-emptions that shape our reality.

When speculations become informative for widely impactful political decisions, business enterprises, and creative endeavours, their inherent unreliability urges active challenges and corrections, which are not the prerogatives of techno-elites or any other exclusive socioeconomic stratum. Such ideational constructs should become objects of socially inclusive and democratically framed interdisciplinary scrutiny, and their suitability for policymaking and susceptibility to instrumentalization must be carefully deliberated. Given all conceptual weaknesses and knowledge deficiencies in AI and other transformative technologies, this deliberation should be sceptical while remaining open to potential breakthroughs. Crucially, it must not disregard immediate, imminent, and mid-term problems in favour of gambling intellectual and material resources on dreamed-up projections of an unpredictable future.

Facing the scope and intricacy of AI science and technology and their economic and political power games, these closing notes may serve only as generic suggestions for devising more comprehensive and robust public oversight and regulatory mechanisms. Defining recommendations for a responsible and socially productive engagement with AI imaginaries, exploring speculative AI's subtler effects in academic and techno-scientific sectors, and investigating its influence on art practices, education, and other forms of cultural production requires further work.

Notes

1. For instance, the plots of Isaac Asimov's novelette *The Bicentennial Man* (1976) and the film Wings of Desire (1987, directed by Wim Wenders) are built upon the assumption that sophisticated non-human entities would strive to become human and gladly accept all the oddities that come in the package (Asimov 1976; Wikipedia 2025).

2. Science fiction writer L. Ron Hubbard materialized these phantasies in a series of lucrative projects. He devised a mental therapy system called Dianetics and published it in the Astounding Science Fiction magazine in 1950. Despite the overt criticism from scientific and medical communities, Dianetics attracted a wide following, and Hubbard used it around 1952 as a basis to create Scientology, which quickly became a conglomerate of religious beliefs and often illegal business enterprises (see Behar 1991).

3. Noting that definitions of AGI and ASI vary (see Eliot 2024), I refer to their most common versions in this paper.

4. See, for instance, Ryle (2009).

5. For a more detailed discussion and examples of AI speculations in the computer science and AI industry, see Mitchell (2019a, 223–225; 2019b).

6. Existential risk studies should not be confused with the field of AI safety research, which deals with the present issues of conceptualizing, designing, and controlling safe and reliable AI systems.

7. Bostrom's earlier simulation argument article (2003) and latest book (2024) are also constructed around computationalist postulates.

8. Other influential existential risk scholars and works include Max Tegmark (2017), Sam Harris (2019), Toby Ord (2020), William MacAskill (2022a), Martin Rees, and Phil Torres. For the field's intellectual history, see Moynihan (2020).

9. For a further discussion of the techno-utopian complex, see Cremer and Kemp (2021, 2–6).

10. The Future of Humanity Institute at the University of Oxford, which Bostrom founded in 2005 and directed until its closure in 2024, enjoyed financial support from Elon Musk and Dustin Moskovitz, one of Facebook's co-founders. Musk and Moskovitz are also among the primary funders of the effective altruist Open Philanthropy Project, which has emitted 412,537,862 USD in research grants for studying AI risks between 2012 and 2024 (Open Philanthropy 2024). Skype cofounder Jaan Tallinn and Ethereum cofounder Vitalik Buterin co-founded the Future of Life Institute, a think tank that studies AI-related existential risks. Musk sits on its the advisory board at the Cambridge Centre for the Study of Existential Risk (Cremer and Kemp 2021, 1; Schuster and Woods 2021, 6; and RationalWiki 2024a).

11. See Cremer and Kemp (2021, 4–20) for a more detailed discussion.

12. It is also notable that transhumanism was initiated in the twentieth century by prominent eugenicists such as Julian Huxley (1968).

13. See, for example, Kauffman (2016).

14. These critics are joined by AI risk and safety researchers who offer more nuanced reflection. See, for example, Vallor (2024), Kasirzadeh (2025), and Gyevnar and Kasirzadeh (2025).

15. Analytic metaphysics attempts to arrive at conclusions about the material world by just thinking about it, which is ultimately a futile enterprise because endless hypothetical realities bear little relevance to the singular reality that we know of. Science provides empirical evidence that narrows down the possibilities from logical to physical (Pigliucci 2021).

16. For further discussion about the technical issues of future AI scenarios, see Verdicchio (2023) and Narayanan and Kapoor (2024, 150–178).

17. See Smil (2019), also Tetlock and Gardner (2015) who show that even the most successful forecasters' predictions reaching three to five years into the future default to chance (guessing).

18. Anthropic CEO Dario Amodei's wordy essay "Machines of Loving Grace" (2024) and OpenAI CEO Sam Altman's TED talk (2025) are two other instances of eloquent but misleading and self-serving corporate rhetoric which rephrases radical techno-utopian visions of the future AI goodness.

19. See Morozov (2013).

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Providing Form to Function: Exploring Code Through Visualization

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As digital spaces increasingly shape our daily lives, there's a growing need to better comprehend how the software we use functions. Relying on digital technology without understanding its workings diminishes user agency, and a lack of understanding reduces its accountability. However, by learning about how software operates and its constructed, we can reclaim agency in the digital technologies we use. Throughout this paper, we explore the relationship between digital literacy, computational thinking, and agency, and argue that information visualization can serve as a transparent method to make abstract code more accessible. *Exploring Hidden Worlds* is an exploratory tool that merges information visualization and programming language analysis to visualize code in three-dimensional space. This interactive approach empowers users by enabling them to explore code at their own pace and uncover the underlying structure of software development. The project draws from computer science, information design, communication design, and user experience design to envision a novel way to interact with the intangible nature of code.

1. Introduction

In our daily lives, we interact with numerous digital interfaces and experiences, making each scroll or button press feel insignificant in the grand scheme of things. While interacting with a single social media post or writing an AI prompt may seem inconsequential, collective interactions can lead to significant effects on our behavior. However, users often have limited control over changes to frequently used interfaces as they are updated and streamlined (Chun 2016, 2), particularly when it comes to aggregated personal data. The fields of user experience and communication design are grappling with issues related to "the digital" (Stambler, Veeramoothoo, and Davis 2024), and to better engage with and retain agency in increasingly digital spaces, there is a need to enhance our understanding of digital environments and how they are constructed. If we were aware of the ways our data is collected and the attention it draws from us, our relationship with digital technology would likely be different. Following the argument that intelligence is a form of agency (Satyanarayan and Jones 2024), by understanding how software works and how it is constructed, we can regain some control over the digital

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technologies we use. Though there is a push to teach programming skills and computational thinking through abstraction of algorithms, it is equally important to consider the impacts code has both within the function it makes and the impacts on users of software.

Meanwhile, digital data serves as a valuable resource for informing public policy, scientific discoveries, business strategies, and our personal lives (Heer and Shneiderman 2012). It becomes particularly advantageous when combined with information visualization's ability to simplify complex information (Abbate and Marino 2022). Information visualizations act as a medium for knowledge transfer, making them well-suited for teaching people about how software is built. In conjunction with information visualization, interaction design plays a significant role in enhancing cognitive abilities within a visualization system (Dimara and Perin 2020). Interactive visualizations also encourage users to explore and comprehend data at their own pace, providing a deeper understanding of causes and effects that might otherwise be challenging to discern (Abbate and Marino 2022). Programmers have recognized the benefits of visualizing code, leading to the development of various tools that utilize visualization as a method for code comprehension (Hawes, Marshall, and Anslow 2015; Balzer, Deussen, and Lewerentz 2005; Wettel and Lanza 2007). These tools were primarily designed for engineers and developers, and outside of classroom settings, there are limited efforts to educate non-technical audiences about the ways software works.

Throughout this paper, we will begin by reviewing existing literature on user agency within digital technology, its relationship to digital literacy, and computational thinking. Following, we present *Exploring Hidden Worlds*, an exploratory tool that utilizes information visualization and programming language analysis to visualize code with a three-dimensional space. We argue that information visualization can enhance user agency by revealing how software is constructed, and in turn be used as a method for computational thinking. *Exploring Hidden Worlds* draws from various disciplines, including computer science, information design, communication design, and user experience design, to envision and explore a novel approach to interacting with the intangible nature of code.

2. The Need to Understand Code

As a collective society, our inability to understand software and its impacts separates our agency from the responsibility of technology companies. The separation allows software to act independently and

with less accountability to its users as it marches forward towards its own goals. In addition, with the development of generative AI tools, software is taking a larger role in thinking while having little accountability to the users it serves. Satyanarayan and Jones suggest that:

> If agency is the capacity to act as an agent, accountability is the capacity to give an account of why one acts in the way one does—an explanation of how an act meaningfully advances or addresses a goal—and hence to be held accountable by oneself and others. (Satyanarayan and Jones 2024)

We have become so used to the offering of technology and new software, embedding it into our day-to-day lives that the ways our experiences are shaped by it have become invisible and deceptive (Stambler, Veeramoothoo, and Davis 2024). The goal to improve our understanding of digital technology lies in the fields of computational thinking and digital literacy. Both are related to one another, and though definitions differ, digital literacy is thought to involve skills to understand and use information from different digital sources to solve problems related to access and selection of information. Whereas computational thinking consists of problem-solving and understanding human behavior through processes of abstraction, creativity, mathematical skills, and innovation (Stambler, Veeramoothoo, and Davis 2024; George-Reyes, Rocha Estrada, and Glasserman-Morales 2021). Strengthening computational thinking skills does not require knowledge about how code is represented, or in other words:

> Computational thinking is far away from performing activities that involve writing computer code instrumentally; in other words, without mediating knowledge about the representation of the reality of the code that is being written. (George-Reyes, Rocha Estrada, and Glasserman-Morales 2021)

Therefore, understanding code enhances computational thinking, leading to increased agency when using digital devices. Filbert articulates this argument effectively, as seen in their summary:

> The ability to maintain a critical and relatively free participatory relation to increasingly computable technologies ambient and 'everywhere' must include comprehending their ontology and epistemology; design, purposes, and use; social and political functions and intentions; and be capable of altering and effecting change within them. (Filbert 2021)

Meanwhile, programming is a difficult skill to learn. Not only from the complexities and nuances of programming languages, but because of its requirement to be highly explicit (Guzdial 2008). The initiatives to improve education around programming have centered around concepts in digital literacy and computational thinking, but the fields are often ill-defined (Filbert 2021; George-Reyes, Rocha Estrada, and Glasserman-Morales 2021; Tamatea 2019). Within the effort to teach young students to code, the undertaking risks being too precise, restricting it to skills only within computer science, whereas others argue computational thinking should teach people how to exist within digital environments (Tamatea 2019). While there is disagreement over what computational thinking and digital literacy entail, researchers agree that a need exists for people to become more informed about digital technology. The ideas can be combined in a way that focuses on understanding the impacts that the structure of code has on the ways we use it. After all, if architecture informs our relationship to space (Markus 1993, 12), code informs our relationship to software.

One method to show the nuances of code is information visualization. The discipline is often used as a method to convey complex information into a simplified, easier-to-read, visual form (Masud et al. 2010). The benefits of visualizations have not gone unnoticed in computer science, and examples of visualizations for code have existed for some time (Hawes, Marshall, and Anslow 2015; Jbara and Feitelson 2014; Balzer, Deussen, and Lewerentz 2005). However, these approaches focus on visualizing code to improve code comprehension for engineers, and one drawback when it comes to code visualizations is their inability to match a developer's mental model of a codebase (Heinonen et al. 2022, 34). Simultaneously, few visualizations exist for a non-technical audience, a group that has little preconception of what code looks like but could benefit from one to improve their understanding (Tamatea 2019). Following the argument, in which a user-centered design approach to information visualization is both an outcome of the visualized "raw" data and a "transformation process" that results in the communication of new knowledge (Masud et al. 2010). Similarly, knowledge can be differentiated from information as something structured and hierarchical, resulting from a refiner's process (Cleveland 1982). Specific types of visualizations — formative visualizations — support "knowledge transfer inside cooperative work groups" to "represent workflows, processes" that can "instruct users of their role in that cooperative context" (Masud et al. 2010). The design of novel visualizations can directly aid in the transfer of new knowledge. Specifically, knowledge of how software is built. A common argument for the need for visualization is due to the increasing digitization of in-



Fig. 1. *Exploring Hidden Worlds* visualizing the open-source project Leaflet.

formation and relationships, along with the diffusion of data generated by people and organizations, each representing both a challenge and an opportunity to design tools suitable for the complex and changing environment in which we live (Abbate and Marino, 2022).

3. Giving Form to Function

Complex pieces of software can be thought about in terms of lines of code (LOC), or for exceptionally large projects, millions of lines of code (MLOC). With the frameworks that currently exist, it is common practice for engineers to only understand the subset of code they work on, and rarely have an understanding of a codebase as a whole (Hawes, Marshall, and Anslow 2015). *Exploring Hidden Worlds* attempts to create an explorable 3D visualization to give form and materiality to the intangible and difficult-to-understand infrastructure behind software, and due to the immaterial nature of code, a new visual form may be needed to effectively visualize it. The project was developed as an investigative exploration to imagine a new way of conceptualizing code. The visualization combines the hierarchical structure of a software project, from nested folder, file, and statement relationships, with referential relationships. Such as when a function invokes code from a different file. The interface is presented in a way for users to explore the novel form, and by placing the visualization in 3D space, it invites users to pan, zoom, and interact with the visualized code however they choose. Through the interface, user agency is encouraged to explore and interact with the data as they see fit, rather than enforcing a single point of truth within the visualization. The goal of the tool was to build a visualization that required little to no knowledge in programming and code to read. Following the definition of a knowledge visualization, *Exploring Hidden Worlds* aimed to help

transfer knowledge about the ways software is built from engineers to the users of the tool (Burkhard 2004).

3.1. Collecting Data

In order to build the visualization, a custom static analysis tool was written and tested with a series of open-source projects written in JavaScript. The analysis would recursively navigate through a project directory and identify JavaScript files, and proceed to identify control statements within the code (conditionals, loops, classes, interfaces, etc.) in addition to flagging statements which referenced code imported from other files. Each of the node and edge types are based on fields within a customizable schema that was used when parsing a codebase and identifying statements within code. The schema allows for a variety of programming languages to be parsed and visualized according to different syntax. The resulting analysis was then exported to a JSON object that would be independently rendered.

```
{ “language”: string
  “keywords” string[],
 “keywordsToIgonore”: string[],
 “source”: string,
 “root”: string }
```

An example of the configuration schema used by *Exploring Hidden Worlds* to analyze a codebase.

3.2. Why 3D

The visualization was developed with a 3-dimensional force-directed layout in mind to engage users by generating a more visually appealing composition, and to encourage the use of different methods of interactions to explore the network. By panning and zooming around the visualization a user becomes an active participant to figure out how different pieces of code are connected to one another, and how each node and edges informs the overall structure of a codebase. Additionally, the extra space afforded by the 3D navigational axes allows the nodes and edges within the network to be spaced out as opposed to a more traditional 2D network (Gummesson 2016). While the spatial layout introduces new challenges such as difficulties retaining orientation throughout the visualization, the obscuration of data as nodes can exist outside the viewable window, or by simply being placed further away in space. The drawbacks introduced by this novel form of visualization are diminished due to the objectives of *Exploring Hidden Worlds*. The tool was built to not act as a single source of truth

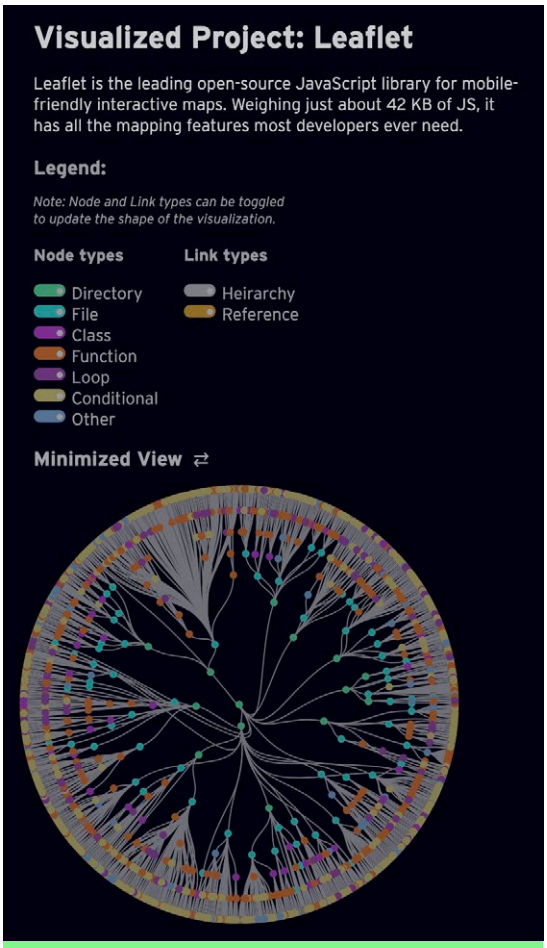


Fig. 2. Focused view of the elements within the legend.

for a user to wholly understand a codebase. Instead, much like the way an engineer approaches a codebase, a user can navigate around code using the tool to understand small portions of the visualized project. Specifically, they can pick out portions of the visualization which they find interesting and choose to dive deeper.

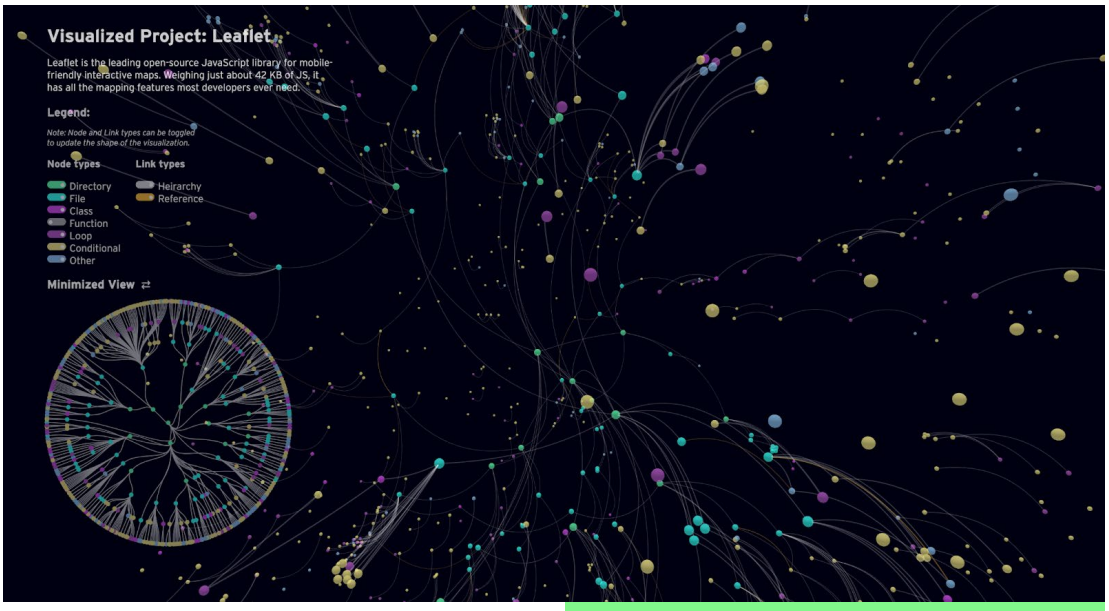


Fig. 3. Filtering out function nodes through the toggle-able legend.

3.3. About the Interface

Split into three pieces, each part of the interface utilizes concepts from information and visualization design, creating an aesthetically appealing visualization to reinforce the interactions and controls a user can do. Following Ben Shneiderman's seminal mantra "Overview first, zoom, pan, and details on demand" (Shneiderman 1996). The tool focuses on giving users a general overview of what code can look like. Only by interacting with the visualization and resulting information granularity, can a user then understand the code behind it

The legend (Figure 2) serves as the primary guide for users to understand the visualization along with: teaching a user how to read the visualization, and act as a method to filter the data and view the resulting modified data. Each type of node and edge that exists within the visualization is also toggle-able and dynamically updates the shape of the visualization when interacted with.

After each filter the 3D network is re-rendered, and the new form allows users to focus on specific pieces of data while reducing the complexity of the visualization in both the 3D network and 2D dendrogram (Figure 3 and Figure 4).

Beneath the legend sits a minimized view of the visualized code in the form of a radial dendrogram. The secondary visualization exists to showcase the structure of the code in a more familiar 2D representa-

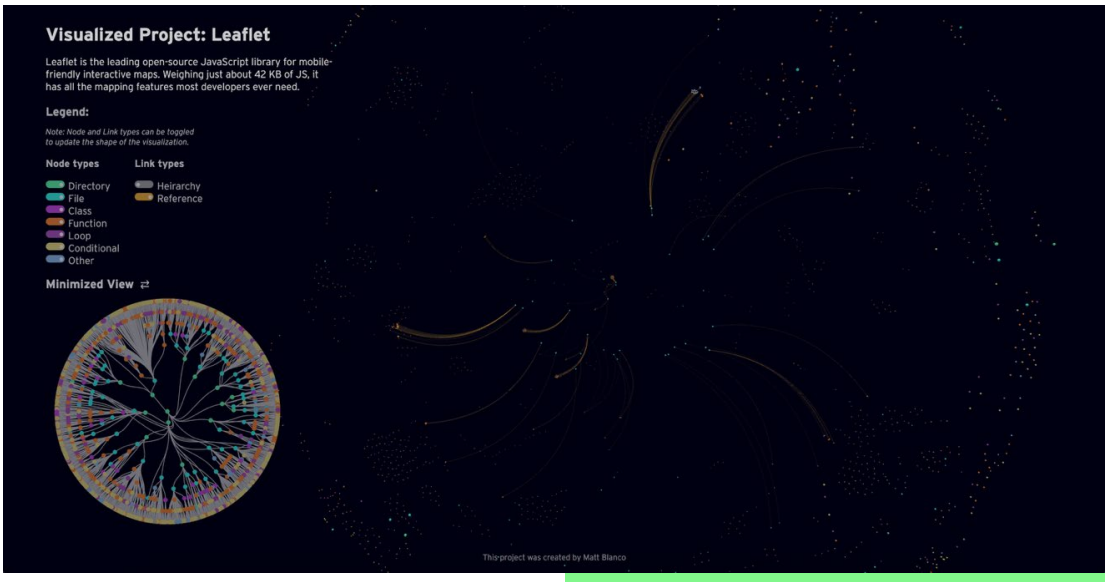


Fig. 4. Filtering out hierarchical edges through the toggle-able legend.

tion. Highlighting a node within the dendrogram will automatically move the user's camera to the node in the 3D network to edge the two visualizations. The user has the ability to change the views of the 3D and 2D visualizations if they prefer to interact with one over the other, and hovering over a node will highlight it in both visualizations to visually edge them. The added interactions and purposeful design attempt to improve readability when using the tool.The central focus of the tool is the 3D network shown front-and-center when first opening *Exploring Hidden Worlds*. Situated in the center of the visualization sits the root directory of the project, and expanding outwards are child directories, files, and eventually individual code statements. What would be a simple hierarchical tree diagram becomes more complex when referential edges are added to the network, turning the visualization into a more circular form.

The force-directed layout creates an engaging and dynamic animation as the visualization first loads and slowly cools down, inviting users to pan and zoom. Meanwhile, the visualization provides methods of information granularity by highlighting the first line of code or file name when hovering over nodes and displaying a tooltip of code that the node is representing.

Exploring the rendered codebase relies on a user's curiosity to navigate the visual representation of code at their own pace as opposed to providing an entry point to read the visualized data. Each part of the interface helps make navigating the visualization as easy as possible, and exploring the visualization creates a space for critical engagement with the infrastructure we are increasingly relying on. The goal is to use our technology thoughtfully and intently, or as Satyanarayan and Jones suggest:



Fig. 5. Information granularity when interacting with nodes.

> Within [a user's] capacity to act, they can strategically compose their own actions according to means–ends calculations and interpret the efficacy of their action on the world. Thus, each independent agent is engaged in an ongoing dialectical process of compositional and interpretive activity: acting with purpose and monitoring their action. (Satyanarayan and Jones 2024)

Through the visualization, a user can view the different design patterns present in a codebase, see clusters of nodes indicating which files are more complex, and see which files rely on other parts of a codebase. When paired with the information granularity within the visualization, a user can further investigate how specific portions of code work (Figure 5). The visualization provides a new material when it comes to understanding code, giving visual form to function. While reading individual lines of code with the 3D network is difficult, a user can better conceptualize the scale that software projects can take.

4. Conclusion

Software will continue to streamline all aspects of our day-to-day life, and augment the ways we think. Though it is our responsibility, as users of technology, to rethink how it gets utilized. There is a connection between having an understanding of digital technology through computational thinking and agency over software. However, passively relying on digital technology diminishes our agency, but it can be regained through critical engagement with code. The ongoing discourse on computational thinking and digital literacy underscores the necessity for novel representations to comprehend and interpret code among non-technical audiences. Information visualization is

particularly suited to shed light on the intricate nature of code due to its ability to translate information across domains of expertise and simplify complex information. Visualizations are also enhanced when combined with interaction design techniques by providing methods to explore visualized data such as data filtering. *Exploring Hidden Worlds* offers one solution to see how software is constructed by presenting a novel approach to visualize code. Each aspect of the interface, from the 3D network, filterable legend, and hierarchical 2D dendrogram, create a variety of interactions for a user to navigate the visualization, and the combination of design and programming methods used created an engaging interface for users to freely explore code. The project sought to develop an engaging method for learning and visually representing the digital material of code. As people gain a deeper understanding of how code influences their daily lives, through the interfaces we interact with and the data software collects, they can exert greater control over how digital technology seamlessly integrates into their lives.

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Fauxtanical: Co-creation with the More-than-less-than-human

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How might humanity complicate empathy by 'feeling along' with an artificial plant? Michael Marder, a philosopher of 'plant-thinking,' argues that human empathy toward real plants is limited by anthropomorphism, as we are simply projecting our notions of experience onto them. *Fauxtanical* is a practice-led research project which aims to extend Marder's line of inquiry as to also consider the experience of non-living 'fake' plants through a participatory installation. *Fauxtanical* utilizes bio-signal data gathered from a real plant, its artificial doppelgänger, and a human source to allow for collaboration between human, machine, non-human, real, and faux - occupying a liminal space between the actual and the virtual. Drawing from non-representational methodologies of performatively procuring and visualizing 'non-data' from the artificial plant, a chance-driven audio-visual immersive experience mediated through cymatics, screens, and speakers emerges. A posthuman dialectic helps contextualize conceptual components and provides its distinction from similar research within a critical media practice. Taken alongside a reframing of ancestral notions of animism reveals *Fauxtanical* as not only a critique of anthropocentric empathy through exploring the possibilities of artificial agency, but also as an experimental form of embodiment with the more-than-less-than-human, perhaps fostering novel schemas of empathy to bloom in the in-between.

1. Introduction

Faux (noun): Made in imitation; artificial. Not genuine; fake or false.

-tanical (suffix): The study and appreciation of (...)

Fauxtanical: The study and appreciation of an artificial experience.

The relationship betwixt technology, the human brain, and other biological systems in the discourse of contemporary media art has provided humanity with novel methods to *feel into*, or empathize with, different life forms. Amongst these lifeforms are both real and artificial plants, which have taken root in the subterrain of the post-modern and post-human psyche. We find this floral pairing in homes, offices, funerary spaces and within the art gallery. This media art project hopes to complicate the aesthetic agency of an artificial plant by

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Fig. 1. The project in a standby state of no human interaction.

starting from the perspective of the plant in wondering if it can 'render' human notions like empathy and creativity, or 'experience' at all. So, I am artistically interpreting plant experience from the perspective of a human experiencing the real-fake plant duo and translating the collective's 'experience' into audiovisuality that is partly being produced by a plant – at least vicariously. A documentation video of the project can be found here: https://vimeo.com/973358910.

Asking a question like 'can a fake plant experience?' would benefit from some context to better understand the need to ask it. A nice place to start is in 1974, when American philosopher Thomas Nagel asked a similar question – "What's it like to be a bat?". Since then, an apt re-centering has occurred between the 'human-at-the-top' hierarchical approach to studying the study of experience and a movement towards the foci of experience being of non-human and non-living others, informing our humanity. Arguably, it's not a new way of thinking, since some ancestral worldviews and current indigenous cultures/practices have promoted such animist perspectives for some time. Despite the colonialization and domestication of the mind hindering this style of question-asking, it has permeated through the collective psyche. Some contemporary thinkers, like object-oriented philosopher Ian Bogost, asked it more plainly in 2012 – "What's it like to be a thing?". His 'alien phenomenology' grapples with defamiliarizing object-subject relations such that an object's *umwelt* becomes foregrounded (Bogost 2012). Soon after, philosopher Michael Marder proposed *Plant-thinking*, which is the process of bringing human cognition back to its pre-cognitive, non-ideational, and non-representational vegetal rhizome when considering plant life, thus rendering it plant-like, or in Marder's words - "thinking without the head".

There's much to be said about plant-thinking, or at least relational plant-environment 'thinking' — but not enough for *fake plant-think-*

ing. In Marder's shorter article, "The Life of Plants and the Limits of Empathy", he holds that human empathy toward real plants is limited by anthropomorphism, as we are simply projecting our notions of experiential empathy onto them, thus only viewing plant-thinking as humanity perceives it, and not from the thinking-feeling of the plants themselves (Marder 2012). However, this view may risk overlooking a more nuanced role that anthropomorphism can play. As writer Randall Lockwood (2023) suggests, anthropomorphism, when engaged reflectively, can serve as a cognitive and emotional bridge - not to assume sameness, but to *feel with* non-human lifeforms in ways that cultivate attentiveness and ethical regard. In the context of this project, such reflective anthropomorphism may pry open speculative avenues for feeling with not only living plants, but their artificial counterparts as well. Further development of this style of thinking regarding the limits of empathy within anthropocentrism can be found in eco-feminist and post-humanist writer Rosi Braidotti's *The Posthuman*. In the chapter "Post-anthropocentrism...", Braidotti spells out the conditions in which non-human subjectivities in late-stage capitalism have formed and can become brought into focus for the sake of extending notions, such as empathy and creativity, to the more-than-human social relata.

> The emphasis on empathy accomplishes several significant goals in view of a posthuman theory of subjectivity. Firstly, it reappraises communication as an evolutionary tool. Secondly, it identifies in emotions, rather than in reason - the key to consciousness. Thirdly, it develops what Harry Kunneman has defined as 'a hermeneutical form of naturalism' which takes critical distance from the tradition of social constructivism and situates moral values as innate qualities. This is a significant addition to the theory of the nature–culture continuum. (Braidotti 2013, 78)

Much like Marder, Braidotti takes issue with empathy for and of the non-human - for similar reasons having to do with the denial of the specificity of their nuanced ontology within anthropocentricism. For both, the extension of empathy is a noble gesture, but is misdirected. Neither thinker stretches empathy to the non-living, though, there is hope for both. For Marder, plant-thinking becomes a method which allows one "[...] to construct their ideal selves or to retrieve alienated features of their own existence" (Marder 2013, 371) in plants, or simply, to recognize the vegetal within us. For Braidotti, empathizing with a plant might be "[...] to see the inter-relation human/animal as constitutive of the identity of each. It is a transformative or symbiotic

relation that hybridizes and alters the 'nature' of each one and foregrounds the middle grounds of their interaction. This is the 'milieu' of the human/non-human continuum and it needs to be explored as open experiment" (Braidotti 2013, 79).

Fauxtanical proposes such a *fake plant-thinking* which extends Braidotti's and Marder's line of inquiry as to consider the causal agency of a non-living fake plant. In the form of a media arts 'open experiment', it allows the user to feel along with a doppelgänger plant through appropriating a method of cognitive science and a method of data sonification and subsequent visualization. In a co-creative act, the implied data collection of the fake plant's 'biosignals' are taken in contrast to a real plant, and from the human, to allow a chance-based soundscape and animation to emerge from their interrelations. By 'chance-based', I am referring to both the playfulness of chance operations as an artistic research method and the atmosphere in which the entire system is situated in, being that it is open to environmental variables such as the flux of temperature, humidity, and human presence. Environmental entropy may cause biological 'stress' for the real plant, which, according to (Khait et al. 2023), could both propagate airborne ultrasonic soundwaves from the plant and help humans identify its species in the analysis of the soundwaves, "[...] altering the way we think about the plant kingdom, which has been considered to be almost silent until now" (1333). Within the recognition of human presence and behavior being a factor in the production of stress for a plant, there lies a lesson in empathy in realizing that the human can also be a source of comfort and care.

To begin to wonder what it's like to be a fake plant, one might consider a comparison to its closest relative – a real plant. This project chose to employ the species colloquially known as the Snake Plant (*Dracaena Trifasciata*), placed in contrast to it's rendering. Being a highly domesticated species, as it ranks perpetually in the top three most popular houseplants, the Snake Plant's experience might be worth examining as a case for the extent to which 'empathy' can be extended. It's a prime cultivar to evaluate the 'domestication syndrome', which is partly concerned with how human intervention has affected the coevolution of species and their agricultural propensity over time (Fuller et al. 2023). Other aspects of the literature on the domestication syndrome are interested in how chosen phenotypes of a plant go through a process of becoming ornamental, as discussed by (Altman et al. 2022), ornamental plants "[...] have attracted people's senses and aesthetic emotions for millennia, triggering the domestication of many species... they are now a commercial success" (125).

Decorative ornamental plants, like the Snake Plant, are unique in the plant kingdom because their domestication is not associated with agricultural products. Rather, they exist solely for the aesthetic allurement of the human sensory apparatuses, having co-rooted with socioeconomic changes and new scientific technologies regarding the production of their simulacra. This project is performing metaphoric and epistemic work by transplanting the notion of the domestication syndrome over to the faux. In doing so, a spectrum between the often dichotomized real/artificial binary is posited in that a fake plant may have *a type of* experience, or at least a history of experience, when considering its production. This *fake plant-thinking* would propose that a meta-materiality of the *representation* of the domestication may illicit a 'post-empathy' that need not be rooted in the real. In thinking through the extracted minerals that constitute a fake plant's disposition, imaginably, colonist practices extend even into the artifice, since most synthetic plastics are rendered and refined out of raw materials. Both real and faux plants are 'organic' in their carbonic origins, though their temporal existence and production contrasts heavily with the earthly, rooted life of real plants.

2. Related Work

Fauxtanical hopes to deterritorialize the subjectivities between real, faux, and human. It's use of emergent technologies such as EEG (electroencephalogram) and bio-data sensors hope to invite users to empathize and co-create with each agent through mediated interactions. Multiple artworks by the Austrian-French artist duo Christa Sommerer and Laurent Mignonneau deal with themes of human-plant interfaces, data visualization, and 'virtual plants', such as their works *Interactive Plant Growing* (1992), *Trans Plant* (1995), and *Eau de Jardin* (2004), as discussed in *The Artwork as a Living System* (Ohlenschläger et al. 2023). In some other early media works which use sensing technologies to meddle in biological systems, (Steiner et al. 2017), empathy for real plants was the focus of representing plant perceptions. A similar motif is found in Misha Rabinovich's 2016 project, *Raised on Youtube*, which used crowdfunded and crowd-fueled video content to bring life and light to plants (Rabinovich 2016). More contemporary bio-sensing technologies has provided artists a means to synthesize plant and machine data in the exploration of the 'intelligence in nature'. This can be seen in Slovenian artist and biologist Špela Petrič's 2020 project, *PL'AI*, which utilized an AI monitoring system to aid a plant's 'play'. Others have utilized machinic perception in plant-machine interactivity (McDermott 2019), (Sareen and Kakehi 2023), (Hu et al. 2021), while some artists have used EEG

and instrumentation for sound production exclusively (Park 2014), (Leslie 2016). Elsewhere, networked plant activity, such as (Biomodd 2009) and *Synplant*, ideated by Youyang Hu et al., which creates a soundscape based on the environmental variables collected from a group of plants, have continued to foreground plant perception. Some other artists use renderings of the environment (Katchadourian 2021), while others use renderings of the environment in tandem with a live video feed, such as *A Reflected Landscape*, developed by Timur Si-Qin (Si-Qin 2016). Artist-researchers are developing a terrain in developing systems where the relations between plants, brains, and machines can help build better visual ecologies between the environment, its communication channels, and its representations. *Fauxtanical* adds to this ongoing discourse by developing a non-representational methodology of performatively procuring and visualizing 'non-data' from the artificial plant.

3. Methods

This project utilizes signals from three sources – the brain of the human user, a plant, and a live video feed. Their combined output is ultimately transmuted into a generative audio-visual demonstration. The co-creative act starts with the real plant's connection to a bio-sonification apparatus, which is a means to make sound with the micro-fluctuations within a plant's electrical current. The same sensor is attached to both the real and artificial plant, which can be seen in Figure 2. Electrical fluctuations metamorphose into MIDI signals, producing raw, unprocessed sound from hidden speakers beneath a nearby hollow boulder. In a non-participatory state, much like that of Figure 1, the plant produces the soundscape on its own. When a user places the EEG device on, which is a consumer-friendly type known as Muse, visualized in Figure 6, the soundscape changes based on the measurement of the user's mental state as coordinated, and hypothetically as conditioned by, the 'state' of the real and fake plants. The co-creative soundscape forms from how the EEG data interacts with the plant data.

Visually, there are four methods overlapping. Most prominent in this project is the video monitor, which is also 'planted' with soil. The screen displays the plant-derived bio-sonification data in real time via a patch developed in Touch Designer. The generative animation takes on the hue and shape of ripples in water. The plant data stream is also visualized in a small body of water that sits atop the hollow boulder. The body of water atop the boulder makes use of cymatics as an archaic method of data visualization. The animation changes when the user places the EEG monitoring system on, both on the screen and in the water, and on a nearby handheld monitoring device.



Fig. 2. Electrical conductivity sensors attached to plants. The monitor and webcam.

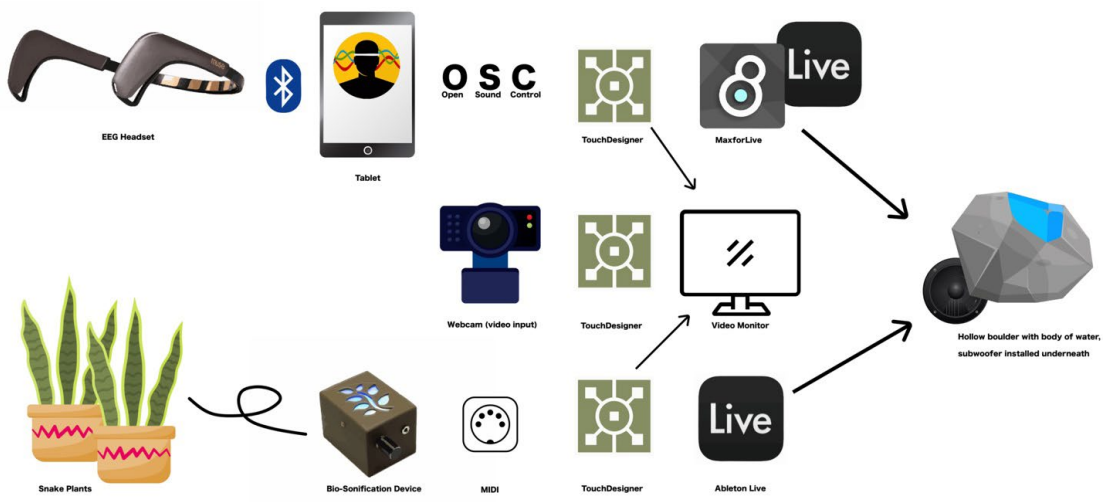


Fig. 3. Signal flow, stemming from three sources. Signal moves from left to right, generally.

The EEG-based animation is in constant flux based on the measurement of the user's mentality, which fused together with the plant's animation, resemble the same sphere-like shapes found in water interacting physically with sound. The EEG system senses all known bandwidths, though this project chooses to highlight the gamma bandwidth. Gamma, which is brain activity roughly within 25-100hz, is often associated with 'flow' states, high levels of coherence in the brain, and the elusive meditative state (Lutz 2004). Once the headset is placed on the user, the gathered data is sent via Bluetooth to a nearby iPad displaying the raw data, then via OSC, it reaches a computer, where the gamma range is selected from the raw signal. The gamma range is responsible for controlling a few parameters in this project: The speed and color palette of the animation, the pulse of the soundscape, and the opacity of the live video feed, which is provided by a webcam mounted to the top of the video monitor. So, when there is 'low' gamma activity, the user's self-representation is seen fully via the live video feed. When gamma activity is 'high', the mediated self recedes into the background, such that only the overlap of the plant and human animations tango, as seen in Figure 4. The signal flow is illustrated in Figure 3.





Fig. 4. Interaction at various levels of brain activity. The upper image shows 'low gamma activity'

4. Discussion

In reflecting on the implementation of the methods, it is worth asking 'what is it like to be an audience participant in an art installation with a real and fake plant', as it is ontologically different than asking 'what is it like to be a fake plant'? Most users could not tell the difference between the real and fake plant, one user noting that "it's a really good fake". They assumed that both plants were adding to the overall experience, often inspecting how the wires ran into the monitor's pot, as to infer the causal chains. Once I had mentioned to the users that could not tell the difference that it was a fake plant, they often approached the plant to feel the duo, even watering the fake plant,

and noticing how touching the real plant changed the audiovisuality. Once it was mentioned that the fake plant's sensor was not actually plugged into the apparatus, they were left with even more confusion, as the sensor's wires were implied to be plugged in. For this reason, in evoking a beauty within the causal obscurity, I decided to keep most of the wires buried. I believe that there is a palpable cognitive dissonance occurring here, often stemming from a disruption of pattern recognition. Upon examination and coming into relation with the real/artificial duality, it collapses.



Fig. 5. The hollow 'liminal boulder'. Speakers and other wires are stored underneath.

Marder, Bogost, and Braidotti are not alone in their hinting of the experience of non-human and non-living entities. Social philosopher Jane Bennett's view on the agency and "thing power" of *Vibrant Matter* posits that all matter is alive and active (Bennett 2010). Media theorist Manuel DeLanda's take on *Non-organic Life* also provides much weight to this style of discourse. For Bennett, everyday objects, such as a fake plant, take on socio-political roles in the way they express their affectation in the world. For DeLanda, the autopoietic activity of the meta-material, which has its own tendencies and capacities, is of interest (DeLanda 1992). They are both associated with a philosophical posture known as *new materialism*, which focuses on matter's intrinsic activity and how it relates to social, cognitive, and cultural life. It also generally critiques binaries like "culture and nature", "mind and matter", and, most importantly for this project, "real and artificial". *Fauxtanical* hopes to corroborate the new materialist project by positing a feedback loop between real and artificial in the way that a human perceiving the fake plant may have its affect measured and displayed back to the human akin to the representation of their mental state. Following this line new materialist thinking, I placed 'all organic' produce stickers onto some of the artificial objects in the work. This motif unfolds further in the project in its sculpting of a 'liminal boulder', as depicted in Figure 5. It is liminal considering that in its plasticity, there is also a concrete top to hold water, thus existing in an in-between state between real and artificial. In doing so, *Fauxtanical* hopes to arrange a causally and materially ambiguous thought experiment that evokes a productive and creative type of cognitive dissonance.

4.1. Artificial Animism

Such ideologies concerning the experience and agency of non-human and non-living objects are commonplace within non-Western cosmologies, especially through the animist logics of ancestral cultures' appreciation for the spirit, liveliness, or affectation of inanimate matter. For some, this may appear to be an illogical orientation of mind, yet these worldviews often emphasize the relationality between en-

tities over their categorical separation from humanity. *Fauxtanical* does not seek to adopt animism or new materialism wholesale, but instead draws a line of correspondence between them, recognizing a shared language rooted in relationality.

Building on sociologist Bruno Latour's work of actor-network-theory, Maria Puig de la Bellacasa (2017) introduces the notion of 'matters of care', extending Latour's provocations of a network-based relationality by emphasizing how even maintenance, attention, and speculation become ethical acts of engagement. In *Fauxtanical*, this ethic of care surfaces in the invitation to relate to a fake plant as a co-creator and co-actor, or at least, as a set of creative tools or instruments. This speculative narrative intersects with what anthropologist Nurit Bird-David (1999) calls a "relational epistemology" in her reworking of animism. Rather than viewing animism as a naïve attribution of spirit to things, Bird-David reframes it as a mode of knowing grounded in lived, relational responsiveness between beings - including technologies. If we are working with technology's etymological root *techne* - we might view the artificial plant as an 'art, or craft' in itself, strung together through plastic fibers and strings. Under this logic, *Fauxtanical* evokes a kind of techno-animism, which could construe an artificial plant as a creative agent.

When considering the artificial plant through this tecno-animist and participatory lens, it can no longer be dismissed as "less-than" human simply because it is not biologically alive. Instead, it inhabits what I am calling the 'more-than-less-than-human', an instantiation of a spectrum of existence that extends to plastics and artificial beings in that they too have the capacity to experience, at least vicariously, through the human. The term builds upon David Abram's articulation of the 'more-than-human'. In *The Spell of the Sensuous* (1996), Abram emphasizes perception as a reciprocal act between beings - one that collapses the boundary between subject and object. He writes, "to define another being as an inert or passive object is to deny its ability to actively engage us and to provoke our senses... perception always involves, at its most intimate level, the experience of an active interplay" (Abram 1996, 56). *Fauxtanical* builds upon this view, but questions whether such reciprocal perception is exclusive to natural, 'living' beings. In foregrounding a fake plant – a synthetic, inert object by conventional standards – as a perceptual partner, the project challenges assumptions about the limits of reciprocity and animacy. This techno-animist reading aligns with feminist philosopher of science Donna Haraway's notion of "string figures" in *Staying with the Trouble* (2016), where she advocates for co-creative story-

telling and “odd kinships” across species and systems. Haraway’s string figures are not just metaphors, they are methods of weaving together entangled relations across difference in species and materiality. In this spirit, *Fauxtanical* strings an experimental narrative between the more and less-than-human, between plant and machine, and between perception and representation.

4.2. EEG, Entrainment, and Representation

Cognitive neuroscience encompasses a diverse set of methods, experimental approaches, measuring tools, and applications of technology towards an understanding of understanding. One of which is the use of EEG in this project. Within this method, what it doesn’t involve is literal, direct descriptions of how the brain works, especially when it is taken in context with interactions with artificiality. The brain is simply too complex for that, and the measurement device is simply not granular or descriptive enough. Thus, this method has only captured partial truths based on its attempts to simplify and reduce complexity down to a representation (Burnston 2024). In making an artistic interrelation of this sort, the best we will be able to get is a simplified, and as is the nature of EEG, often quantified representation of the mental state of the user, not how the user actually ‘feels’ about their interaction with a fake plant. The mental process is simplifying itself in trying to represent itself, as the technology has its limits in its current iteration. In psychologist Stephen Kosslyn’s view, this is a crucial consideration to what EEG is actually capable of measuring and is how the technology represents the brain as simply that – a representation – and not what the brain actually *is* or is doing during a given interaction or what is causing the event-related potentials to occur. Kosslyn goes onto say “[...] (using EEG) it is difficult to infer the locus of the neural generator. Not only do electric currents travel across the brain and across the scalp, but they are distorted when they pass through the skull” (Kosslyn 1994, 45). Both internally within the brain, and externally in its relations, EEG is not able to accurately address direct causation, Though it has it’s empirical and representative limits, I believe that there is still artistic potential in the notion of entrainment, which is the process where something like a biological rhythm, or a musical rhythm, is synchronized or brought into alignment with another rhythm or stimulus. In metaphorically entraining a human participant to the biorhythms of a fake plant, there lies another empathetic ‘feeling with’ a fake plant.

4.3 The Measurement of Non-data

Peering into the aperture of reality often referred to as the metaphysical, one might consider that even an artificial plant or fake boulder has a type of interiority. Beyond the plastic and pigments, there exist the same atoms and other sub-atomic particles that constitute a real plant, a human, and for the most part, the rest of existence. The electron, while largely immobilized within the insulating material of an artificial plant, still bears an electric charge and is part of the energetic substrate of matter. The bio-sonification apparatus used in this project may simply not be sensitive enough to detect subtle electromagnetic fluctuations in the plastic; nonetheless, the placement of the sensor on the fake plant implies that something is potentially there to be measured—even if nothingness is the goal. The placement of the sensor on the fake plant highlights the materiality and sensitivity of the apparatus of measurement itself while also evoking self-referential quandaries that hope to question if there exists a quantifiable piece of data to be measured, or if 'interiority' necessitates quantification at all. To be clear, this is not to equate 'interiority' or 'experience' with 'subatomic charge', though there may be philosophical overlap in their shared entanglement with energetic and material processes. In their essay on 'measuring nothingness' and virtual particles, physicist and feminist philosopher of science Karen Barad, drawing from a Copenhagen interpretation of quantum mechanics, argues that measurements are not merely passive observations but "agential practices" that participate in bringing forth the very phenomena being measured: "measurements are agential practices, which are not simply revelatory but performative: they help constitute part of what is being measured... Measurements are world-making: matter and meaning do not pre-exist, but rather are co-constituted via measurement intra-actions" (Barad 2012, 6). Though there is much debate in the philosophy of science regarding the epistemic affordances of 'measurement' in the Copenhagen interpretation, as it is assuming a conscious, presumably human, subject as necessary in measurement and is assuming that quantum-level happenings have any relation to macro-states – artistic license enables the conflation of these definitions to explore alternative forms of meaning-making through what might be called *non-data*. Rather than treating null or non-data as failure, it becomes a speculative threshold.

As the adage goes – 'even non-data, or null data, is still data'. Here, *non-data* signifies a seemingly absent or negative result – not because nothing occurred in the measuring, but because what occurred lies beyond the thresholds of the apparatus, or outside convention-

al paradigms of detection. It marks a kind of deferred presence: an indication that something may be happening, but not in a way that our tools or minds are prepared to register. For the scientist, after attempting to capture data from the artificial plant, they might return to their hypothesis or experimental design to account for the lack of data. In reflection, they might choose to engineer a more sensitive apparatus, or scrap the venture completely.

For the artist, the collection of non-data takes on a cunning semiotic that aligns well with work being done through 'non-representational theory' (NRT, for short), which simply put, is an interdisciplinary post-post-modernism in the sense that it questions the conditions of contemporary empiricism, amongst other concerns. Extrapolating Barad's discussion of the metaphysical, the non-data collected from the artificial plant in *Fauxtanical* indicates a playful addition to NRT such that it is allowing the artificial to become 'real' so that the plant can be "[...] bursting with innumerable imaginings of what could be" (Barad 2012, 13), containing enormous multitudes of possible states of being that coalesce through the semiotic of measurement. NRT seeks to, according to an introduction by Phillip Vannini, view performance as a research method. NRT aims to make research "more performative" and advises practice-led research interested in alternative uses of scientific methods such that research can "dance a little" (Vannini 2015, 14), resisting the stiff structures of Western empirical science in favor of embodied, contingent, and situated style of knowledge-generation.

Such performative gestures – watering a fake plant, placing sensors on inert materials, interpreting environmental resonance through EEG - do not just simulate scientific procedures; they destabilize their epistemic authority. Some other *non-methods* of knowledge creation are discussed in the NRT literature, and relatedly, in philosopher of science Paul Feyerabend's *Against Method*. Here, Feyerabend argues that there is no single scientific method that can account for all scientific progress, as it is a plurality and faction into different disciplines, such as contemporary cognitive science or physics. He promotes epistemological humility and anarchism, suggesting that "[...] the only principle that does not inhibit progress is: anything goes" for a science that that is interested in the expansion of what we mean by knowledge (Feyerabend 1975, 19). Many of science's greatest advances came from breaking, rather than following, methodological rules. Accordingly, science progresses not through strict adherence to rules, but through creative, sometimes irrational, or even farcical or absurd *science-like* practices. Artist-researcher Erin Manning's ar-

ticle, also titled, “Against Method”, further embraces the fluid nature of creative processes within art and science. She challenges the institutional tendency to impose rigid methodological frameworks on such practices, arguing that these structures can constrain the inherent unpredictability and innovation central to artistic creation insofar that “[...] research-creation proposes new forms of knowledge, many of which are not intelligible within current understandings of what knowledge might look like” (Manning 2015, 53).

NRT informs this project in generating possibilities of an animated encounter with rendered domestication through performative data-gathering. It’s a useful generator of post-truths which defamiliarizes the real and artificial, forming novel odd-kinships and absurd methods of co-creation through the dependent origination of measurement, object of measurement, and measurement-taker. The practice of “measuring nothingness” through artistic means, as is demonstrated in *Fauxtanical*, therefore, should be seen as a significant mode of experimental, experiential and embodied engagement with the mystery that is the brain-body-environment complex. Measuring nothingness is not a failure to measure, but a reconfiguration of what counts as measurable, such that questions like the one proposed here can try to be “restless and willfully immature... NRT work aims to rupture, unsettle, animate, and reverberate rather than report and represent” (Vannini 2015, 5).

Performatively appropriating a method of cognitive science, specifically the brain-computer interface and its subsequent data visualization, not only allows the co-creativity between the more-than-less-than-human to produce a liminal space, but also allows for the user to, according to Marder, “think without the head”, or “thinking” more from the limbic system while the more recently evolved areas of the brain may downregulate. When the user reaches a certain threshold of gamma activity, the user’s self-image dissolves, and along with it, as is the nature of high gamma coherence, maybe their concepts of ‘self’ and ‘artificial’ may dissolve too. Considering that the artificial plant has no ‘head’ to think with, and if we are to take empathy as a ‘feeling into’ something or someone else – perhaps reflecting on oneself feeling into the physiology of an ‘empty’ fake plant might provide a fruitful complication of the partition between user and plant, where the user collapses into, or ‘becomes one’ with, both plants while revisiting empathy for both the real and artificial plant. Perhaps artificial plants have an interiority and type of sensuous capacity that humanity has not been able to find, measure, or prove – yet.

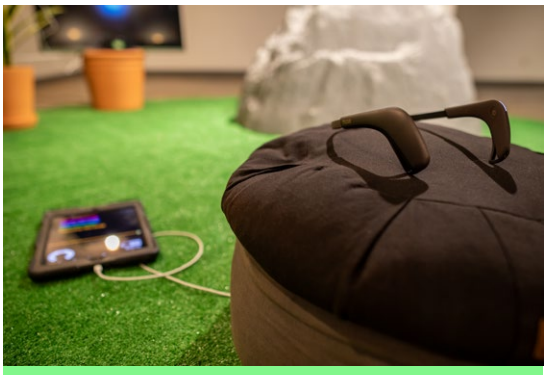


Fig.6. The EEG device sitting atop a Zafu meditation cushion.

5. Conclusion

Engaging with a mode of embodiment that is on a spectrum of more-than-less-than-human, *Fauxtanical* aims to connect humans with nature, both real and artificial. It also aims to connect the entities involved with sound and animation by providing a means to empathize with an artificial plant through a co-creative act. Sounds heard and felt create lasting memory for all involved, as do animations. After providing technical details on the how, the discussion gleans the why – which lies in the semiotic and performative value of attaching a sensor to an object that has no data to give. Here, nothingness is not an absence of data, but an indication of the possible somethingness found when measuring nothingness. Though such an experiment may not subscribe to empiricist methods or common logics, it has been argued that there is still an experimentally experiential type of knowledge being generated. Much like the ancestral animisms that do not fit the mold of western thought steeped in a science that claims to be objective, the knowledge being produced here is othered. In hopes to reconcile with the limits of empathy and the noetic systems which dictate empathy's conceptual extension, this project evokes the experience of everyday objects, detached from human subjectivity, yet brought to life in their immeasurable relations to each other.

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BackChat: When AI Learns Language in Reverse

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BackChat is a language model trained from scratch to generate text and conversation in reverse. Instead of predicting the next word in a sequence, *BackChat* generates what came before, scrambling the assumed temporal direction of thought. Answers produce questions, punchlines lead to setups, and effects precede their causes. Rather than merely inverting text generation, this work challenges the underlying assumptions of AI reasoning, exposing its reliance on statistical continuity rather than human-like cognition. By unsettling familiar patterns of interaction, *BackChat* makes the limitations of AI reasoning more visible and invites speculation on whether intelligence requires causality at all. In doing so, it opens up the possibility of intelligences structured around entirely different temporal logics that do not depend on the stepwise, linear progression that most AI models reinforce.

1. Introduction

In recent years, discussions about Large Language Models (LLMs) have moved beyond technical circles, becoming central in art, academia, and public discourse. The widespread adoption of systems like ChatGPT[1] has raised critical questions about how these models shape language, knowledge, and interaction. Artists and researchers have sought to engage with these technologies not just as tools but as sites of experimentation, asking what LLMs reveal about intelligence, meaning, and the constraints of machine learning architectures (Elliot and Grierson 2024, Zeilinger 2021). This has led to questions, not only about whether these models *think* or *reason*, but about how different architectures might structure intelligence in ways that depart from human assumptions (Audry 2021, Bridle 2022).

Our artwork, *BackChat*, explores these questions through a training intervention: reversing the predictive logic of an LLM. Generative Pre-trained Transformer (GPT) models are trained to predict the next token in a sequence (i.e. next word in a sentence), constructing meaning step by step into the future. This comes from a position that intelligence arises from the brain's ability to predict future events based on past experiences (Hinton 2007). This has led to what researchers have called a *Reversal Curse* where "If a model is trained

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on a sentence of the form A is B, it will not automatically generalize to the reverse direction B is A" (Berglund et al. 2024).[2]

With *BackChat* we invert this structure, by training it to generate text backward, predicting what came before rather than what comes next. Instead of unfolding a story from a prompt of "Once upon a time," we input "*The End*" and the model works in reverse. Instead of asking a question, we enter an answer and see what was asked. Instead of providing the setup of a joke, we give the punchline. This small shift in training alters the experience of chatting with AI, creating a jamais-vu feeling, something conversational but never thinking like a human.

This inversion makes two key aspects of AI clearer. First, it highlights what LLMs are actually doing: not reasoning, but statistically producing the most likely next token based on patterns in training data. By experiencing this process in reverse, users gain an alternative perspective on the fluency and coherence of LLM-generated text. Second, and a little contradictory to the first, it raises the idea of AI having forms of intelligence that do not mirror human cognition. Machine intelligence is often framed in human-like terms, but what if we explored architectures that fully embrace the machine's unique computational properties? Computers excel at tasks that are very difficult for humans, such as writing coherent text in reverse. *BackChat* takes steps towards activating this possibility. Not just critiquing AI's limits, but testing alternative training methods to explore what feelings of intelligence could emerge when we step outside of human assumptions of reasoning.

We situate this work within ongoing discussions in computational arts around Experiential AI, where artistic interventions serve as Explainable AI (XAI) methods that make the mysteries of algorithmic structures "vividly apparent" (Hemment et al. 2023b), and Graspable AI (Ghajargar et al. 2021), which explores how AI processes can be made tangible. *BackChat* pushes further into Speculative AI, not just revealing how current models function but experimenting with changing to architectures to imagine how other intelligences might emerge.

This paper explores the conceptual grounding, technical implementation, and artistic contributions of *BackChat*, positioning it as a method for engaging with AI on its own terms.

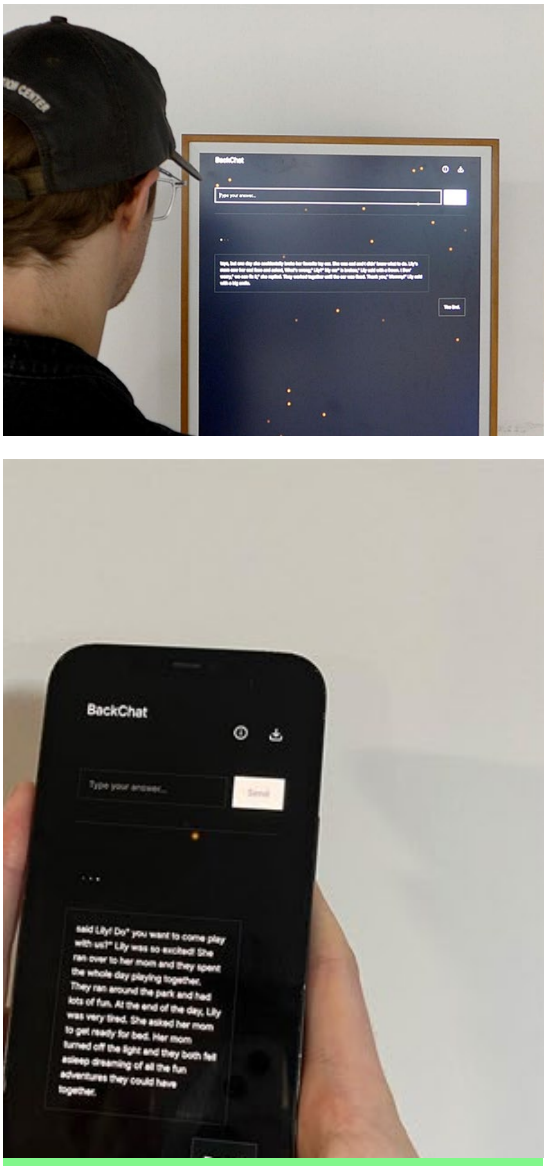


Fig. 1. Photo of the installation version (top), photo of the mobile chat app (bottom).

2. Background

2.1. Explainable and Experiential AI

Explainable AI (XAI) is a field of research originating in computer science that aims to enhance transparency and interpretability in AI systems (Miller 2019). While conventional AI systems often function as *black boxes*, XAI seeks to clarify not only what decision was made, but why the system arrived at that decision. This can involve techniques such as visualising internal model activations, designing surrogate models that mimic the behaviour of more complex systems, and developing analytical tools for monitoring neural networks. The goal is to provide insights into AI processes that would otherwise remain opaque, making models more accountable, understandable, and trustworthy.

Hemment et al. introduced Experiential AI (Hemment et al. 2023b), expanding XAI's focus from explanation to interpretation through experience. Instead of simply offering transparent systems, Experiential AI proposes that users should engage with AI's inner workings directly—feeling its processes rather than merely being told about them. This approach has been used in AI literacy projects (Hemment et al. 2023a). Related to this, in the field of tangible and embodied interaction, is the idea of Graspable AI (Ghajargar et al. 2021), which explores how tangible interfaces and material artefacts can provide alternative ways to hold and comprehend, and in turn critique, AI systems. This aligns with broader research in Tangible AI (McGrath et al. 2022), which suggests that embedding AI into physical objects or interactive environments can allow for a deeper understanding of its mechanisms.

These approaches emphasise that AI systems should not just be explained but made visible, tangible, played with, and interacted with in ways that can reveal otherwise hidden behaviours or qualities. This aligns with the Creative AI Lab's call to go "beyond the study of artefacts to focus on the 'back-end' environments that have enabled their production" (Bunz et al. 2023). In our work we continue with these aims, taking a practical approach that detours from usual implementations of AI, not just to critique AI but to experience how alternative architectures might reshape interaction, interpretation, and experience of alien meaning and reasoning.

2.2. Artistic Interventions in AI and Language

The use of AI in artistic practice has often been framed through a tension between human and non-human intelligence. Artists working

with AI have long experimented with alternative forms of intelligence, showing that machine cognition can introduce non-human ways of constructing meaning (Cohen 1995, Rokeby 1998). These investigations span machine perception, poetics, and methodologies that challenge the conventional framing of AI. Rather than treating AI as a tool that mimics human reasoning, artistic interventions explore AI as systems with their own emergent forms of sense-making.

Orphan Drift's work shows a long-standing engagement with other intelligences found in places such as machine vision.[3] Jenna Sutela's *nimiia cétiï* imagines a system that is not built for human understanding but instead operates as a kind of speculative translation between machine, organism, and abstract form, where the computer is an "alien of our creation" (Sutela 2018) rather than a tool designed to replicate human expression.

Beyond language as an alien system, other artists engage with the structural and poetic potential of Deep Neural Networks (DNN) for text generation, treating them less as models of intelligence and more as dynamic, expressive systems. Memo Akten and Mick Grierson explored how multiple LSTMs trained on different writers' texts can be blended together through an interactive interface (Akten and Grierson 2017). By allowing different AI *voices* to be merged or transitioned between in real-time, Akten and Grierson highlight how AI-generated language is not a singular process but an emergent space shaped by multiple influences. Allison Parrish has also explored DNN as poetic systems, her work highlighting the role training data and model architecture has in shaping outputs, and showing that meaning in AI is often a byproduct of structure rather than intelligence (Temkin 2018).

The works above suggest that language models can be more than passive generators of text, as an active space for rethinking cognition and interpretation. Our work builds on this by introducing a training intervention that alters AI's predictive structure. In doing so we are shifting the focus from what LLMs generate as a static output, to how LLMs construct meaning sequentially over time.

2.3. AI, Time, and Reasoning

Reversing the predictive logic of AI raises a core question: does reasoning require causality? Conventional language models, such as GPT-based systems, operate sequentially, predicting the next token based on past context. This structure reflects a deeply human-centric view of thought, where meaning emerges through forward progression and cause-effect relationships. The AI pioneer Geoffrey Hinton

posits that intelligence emerges from predicting future states based on prior experience (Hinton 2007). Recent developments, such as DeepSeek's R1, reinforce this by optimizing models for "human-like reflection" by rewarding the effective use of <think></think> annotations to signal reasoning steps. (Guo et al. 2025). The underlying aim of most LLMs is to approximate general intelligence, assuming that if AI can mimic human-like thought closely enough, it qualifies as reasoning. This ties into a broader narrative of technological progress as a linear, causal trajectory.

This can be connected to wider debates on non-human temporality and algorithmic reasoning. Parisi challenges the idea that algorithmic operations are merely mechanical computation and argues that machine learning systems develop their own internal logic, shaping how they process and interpret information (Parisi 2016). Rather than dismissing algorithmic reasoning as non-thinking, we must recognise how it is actively shaping our world. Hui extends his critique to the history of technology, contending that technological development does not follow a universal trajectory but embeds distinct ways of thinking and cultural assumptions within its architecture (Hui 2021). From these perspectives, LLMs do not just simulate human thought but develop machine-specific logic. LLMs are producing forms of reasoning that arise from their architectural constraints rather than from any innate understanding.

3. Technical Implementation

3.1 Model Training

To develop *BackChat*, we trained two small language models from scratch using a modified version of smolGPT.[4] We edited the preprocessor and data loaders to reverse the token sequences for training, ensuring that the models learned to predict the previous word rather than the next. To adapt an instruction-tuned dataset we also altered the conversational flow of Dolly (see code block below) so that responses became prompts, reversing the causal structure within dialogues.

```
def prepare_chat_text(example:Dict) -> str:
        context = example.get('context', '').
        strip()

        instruction = example['instruction'].strip()
        response = example['response'].strip()
        if context:full_text = f"Context: {context}\n\nInstruction:
{instruction}\n\nResponse: {response}"
        else:full_text = f"Instruction: {instruction}\n\nResponse: {response}"
        all_words = full_text.split()
        reversed_text = " ".join(all_words[::-1])
        return reversed_text
```

We trained two models on publicly available datasets:

1) TinyStories (Eldan and Li 2023) – a small-scale dataset of synthetically generated stories.

2a) FineWeb (Penedo et al. 2024) – a larger, more general dataset of cleaned web text from the Hugging Face team.

2b) We finetuned our FineWeb model with Dolly – A dataset of instructions and responses from Databricks.

Our models, their trained weights and code, will be made available at this url: https://github.com/isaac-art/backchat. We plan to train a larger model, if there is enough public interest. However, these smaller models already demonstrate the core concept effectively, producing unexpected and interesting conversation. See Table 1 for details of the training runs.

Dataset	Vocabulary Size	Hardware	Training Time	Steps	Final Loss
TinyStories	4096	L40 48GB VRAM	~4 hours	~11000	~1.2
Fineweb + Dolly	8000	H100 80GB VRAM	~ 16 hours	~22000	~2.8

Table 1. Model Training Information

We note here that bi-directional architectures are well established in machine learning research, often used in sequence model architectures and language models such as BERT (Schuster and Paliwal 1997, Devlin et al. 2019). Our novelty here is in re-using a standard GPT LLM model, but changing how the data is fed to it, in order to create an interaction that is new and unfamiliar. In our work the reverse directionality is not just within the architecture of the model but the interaction with the model as well which is an important distinction in how we feel communicating with the 'intelligence'.

By disrupting the familiar cause-effect structure of AI-generated meaning, *BackChat* allows us to question how much of LLM fluency is true reasoning.

3.2. Aesthetic & Interaction Design:

To explore how reversing text generation affects user perception, we designed a web-based chat interface that works on both desktop and mobile (Fig. 1). The interface follows the minimalist design of LLM chat apps (such as ChatGPT or DeepSeek) to ensure familiarity, while introducing subtle defamiliarising elements that make interactions feel slightly off-kilter or unfamiliar.

In our design the text entry box is positioned at the top rather than at the bottom, and the model's response appears above the user input instead of below. The input box is labeled "Type your answer", subtly prompting users to adjust their understanding of their role in the interaction. Words stream into the chat window one at a time as they do with other LLMs, but they arrive in the reverse order making the unfolding text difficult to anticipate in real time.

Beyond reversing interaction flow, we introduced small visual distortions to reinforce the feel of alien cognition and defamiliarisation. Some words subtly wobble, hover, or float making the UI unstable. At irregular intervals, small glowing orange orbs flicker in and out of the background.

For exhibition, *BackChat* is displayed on a large screen, where we play back recorded conversations through the same web interface, selecting particularly unexpected, or poetic exchanges. These examples serve as an entry point, giving visitors a sense of how the model constructs dialogue in reverse and the kinds of interactions it generates. Rather than enabling live interaction on-site, we encourage the audience to access the app on their own devices, allowing them to experience conversing in reverse for themselves.

The app will be publicly available for the duration of the conference at https://chat.thanks.fish. Since we do not run GPUs continuously, the model will only be active during the exhibition period, after this the weights and code will be available to download and run locally.

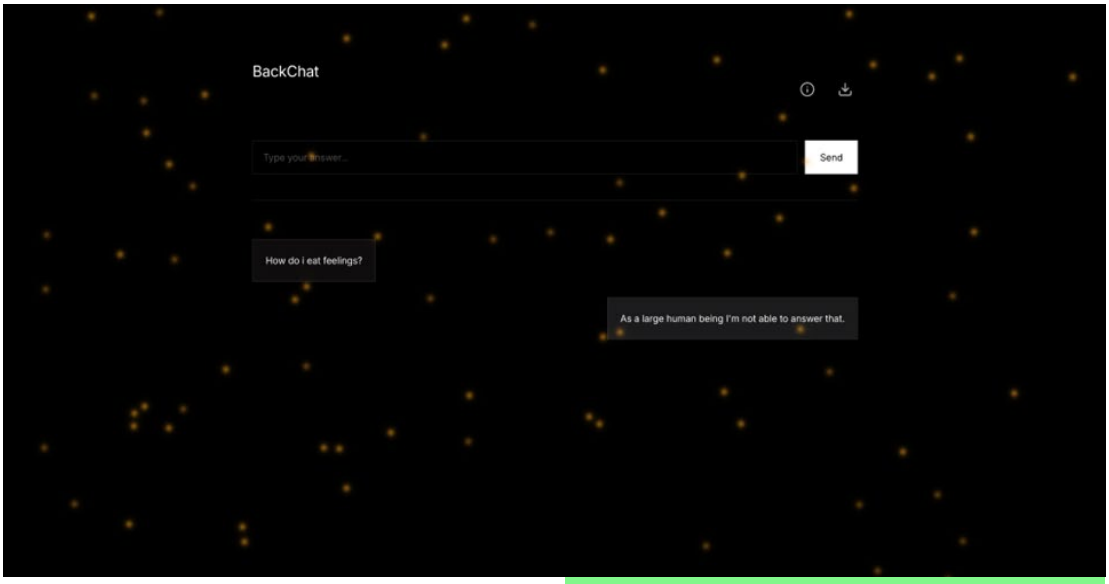


Fig. 2. Screenshot of the web page - User input on the right, model response on the left.

4. Discussion

BackChat offers an experiential disruption of conventional AI reasoning by reversing the predictive structure of text generation. Rather than simply revealing the limitations of LLMs, it creates an alternative mode of interaction that allows users to engage with AI on its own terms. This aligns with Hemment et al.'s Experiential AI framework (Hemment 2023b), which suggests that AI should not merely be explained but encountered through interaction. In this way the AI's fluency, coherence, and gaps become tangible and inhabitable rather than just conceptual.

4.1. Experience of AI in Reverse

To understand how reversing causality affects AI interactions, we present two types of examples: short narratives from TinyStories trained model, where the user provides an ending and the model generates a preceding story, and FineWeb + Dolly trained model conversations, where the user provides an answer, and the model generates a preceding question or prompt.

For clarity, we lay out the text in a way that makes it easier to read. However, it's important to imagine these words appearing in reverse order, unfolding from the user's input backward. In the TinyStories examples, we cut the start of the model's text to give a better sense of the experience: waiting for the cause to arrive, knowing only its effect.

Example 1: Reverse Storytelling

USER: *The end.*

RESPONSE: *...he closed his eyes and took a nice nap. When he woke up, he felt rested and ready to play again. From that day on, Spot learned to be more careful when he played with his friends. And they all lived happily ever after.*

Here, the model generates a recognisable story, but the user already knows its conclusion before seeing its cause. The story feels structured but experientially strange, creating a reverse anticipation effect—where the effect is known, but the cause remains uncertain. This highlights an often-overlooked feature of LLM fluency: meaning often feels rational because of the direction of reading, not because of reasoning itself. *BackChat* makes this evident, allowing users to experience first-hand that AI-generated coherence is a function of statistical prediction rather than structured thought (or at least thought structured as human text).

Example 2: Reverse Conversations – (Fig. 2)

USER: *As a large human being I'm not able to answer that.*
RESPONSE: *How do I eat feelings?*

USER: *You can do that.*
RESPONSE: *Classify each of the following as tooth or ice: abil, sc water, hearts, ys, hockeys.*

Unlike the Storytelling example, where narrative logic remains intact but feels unfamiliar, these Conversation interactions destabilise expectations. The responses are strange, yet not entirely incoherent. The model does not randomly generate text, it produces a response that, in some way, relates to the user input. Again, this demonstrates how AI fluency is often mistaken for reasoning. The oddness of these exchanges comes partly from the small model size but also from the unpredictability of going from effect to cause.

While collecting these samples, it became clear to us that the feeling of the model being intelligent really comes through in its performance, laying out words one at a time. This process of gradual emergence is key to why LLMs feel "alive" to users: we do not see a preformed thought, but an unfolding of text in real-time, giving the illusion of an active thinking process rather than just statistical retrieval.

Unless you are Mary Poppins (Stevenson 1964), reversing the order of words is a strangely difficult task. In Supercalifragilisticexpialidocious, she effortlessly recites the compound-word backward (as

"dociousaliexpilisticfragilcalirupus") - a feat that seems impressive precisely because it is so unnatural. Seeing an AI perform this kind of reversal without hesitation is equally disorienting. The words arrive fluently, but without the usual directional logic that anchors human speech, making the experience feel both intelligent and unsettling.

BackChat plays with LLM Chat expectations. It makes the illusion of coherence more visible while also generating moments where AI's fluency feels strangely convincing despite its non-human logic. This approach highlights a key aspect of speculative AI methods, which we now turn to in the next section.

4.2. Speculative AI Methods

In 2023, a number of OpenAI employees reported experiencing a sense of AI spirituality in the organisation, with the Chief Scientist Ilya Sutskever reportedly leading chats of "Feel the AGI! Feel the AGI!". Strangely, this approach is somewhat in line with methods of our work. AI (as an artificial general intelligence or an alien intelligence) is something that may well be sensed before it is logically explained. Instead of searching to fully explain and align an AI, speculative approaches suggest AI should be engaged with experimentally allowing its otherness to emerge. *BackChat* operates within this framework, curating conditions where the effects of the intervention on an intelligence can be *felt*. Instead of using an existing model in an artwork, we intervene in the training of the model, detouring technological developments, as the artwork.

Much of AI discourse focuses on making models interpretable, often reducing their complexity to fit human expectations of reason. However, artworks, acting in some form or another as an "early warning system" (McLuhan 1964), can allow a different approach. Rather than explaining AI, and "explaining away what may otherwise be visible" (Berger 1972), artistic engagements allow space for experiential understanding that does not discard uncertainty and can perhaps bring us closer to the presence of an intelligence that does not conform to human sense-making.

This approach does not mean AI cannot be understood but suggests understanding may require a different kind of engagement. Through direct interaction, *BackChat* highlights the gaps, frictions, and unexpected logics that emerge between human reasoning and AI's predictive mechanisms. The experience is not necessarily making AI more transparent but can reveal the contours of its own structure through its odd juxtapositions working from effect to cause.

This work invites users to encounter AI not as a tool to be understood, but as an experience to be inhabited. This is what makes speculative AI an interesting method to us. It does not reduce AI to a simplified explanation but instead creates conditions where we can interact with it in new, unfamiliar ways.

4.3. AI, Time, and Illusions of Coherence

AI alignment and interpretability research often work with models that are said to be *reasoning* because they sequence words in a human-like manner. LLMs predict the next most likely token based on past context, creating a stepwise progression of meaning that appears rational and intentional. But what happens when we shift the direction of that process?

Bridle contends that "the way we are constructing artificial intelligence today opens up the very real possibility that future intelligences will be opaque to us" (Bridle 2022). If AI is thinking it does not think like we do, and our efforts to frame it within human cognitive structures obscure how machine intelligence may operate on different principles entirely. *BackChat* exposes how AI-generated coherence is not the result of structured reasoning but of statistical continuity. It shows how fluency can often be confused for thought. In some ways this aligns with Peirce's notion of abductive reasoning, which starts from an observation and infers at the most plausible cause (Douven 2021). We continually push back at an idea that reasoning and intelligence should have to follow the same temporal and causal structures as human experience. Again, we hit up against a "dearth of language" (Gilchrist 2022) with which to discuss the operations of AI.

BackChat does not propose an alternative model of reasoning, nor does it attempt to simulate an alien intelligence. Instead, it makes the limitations of AI reasoning more visible by scrambling the assumed temporal direction of thought. In doing so, we invite speculation on whether intelligence requires causality at all, or if there are other ways of structuring cognition beyond the linear, stepwise progression that most AI models reinforce. Overall, this work is an attempt at recognising the possibility of intelligences that operate in entirely different structures of time and causality.

5. Conclusion

BackChat is a speculative intervention into AI reasoning, demonstrating that artistic approaches to AI can serve as both critique and proposition. By inverting token prediction, it forces us to reconsider how meaning is structured in AI-generated text and how much of our

perception of intelligence is shaped by familiar patterns of conversation and coherence. Through both its conceptual framing and practical implementation, *BackChat* reveals that reasoning in AI is often an illusion shaped by statistical fluency rather than understanding.

BackChat shows how speculative AI artwork approaches can go beyond critique to offer alternative interactions, even when based on small changes made in the training of a language model. Interactions with AI through artistic interventions do not have to fully explain technical operations but can aid in understanding the qualities and edges of these creations.

Instead of aligning AI to human expectations, our project hopes to show that AI could function according to entirely different logics, that can in turn open up new ways of being. Going forward there continues to be space for artistic interventions into technical works that challenge the assumptions embedded in AI technologies, and through artworks we can experience, rather than just theorise, alternative modes of machine cognition.

Notes

1. https://www.chat.com.

2. Also referred to as the Michael Scott syndrome after the character's line "Sometimes I'll start a sentence and I don't even know where it's going. I just hope I find it along the way" (Feig 2008) (via https://x.com/multimodalart/status/1891426729912115311).

3. https://www.orphandriftarchive.com.

4. https://github.com/Om-Alve/smolGPT.

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The project “Transmutations: Aesthetic Explorations for the Subjective Signification of Signals and Data”

The project “Transmutations: Aesthetic Explorations for the Subjective Signification of Signals and Data” focuses on using biological data, such as DNA and other physiological parameters, to transform them into artistic representations. Through translation, transduction, and transcription processes, the project approaches the traditional ways of understanding identity and human experience, proposing subjective and visual representations of the data. Through an integration of art and technology, the potential of biological data to offer meaningful experiences is explored, emphasizing the ethical and political implications of personal and biotechnological data exploration. The transmutation of these data in a context such as art and the digital realm not only raises questions about identity, but also opens a reflection on how technology, culture, and biology are intertwined in the construction of our contemporary being.

1. Introduction

In today’s world, biological data has gained unprecedented prominence, advancing our understanding of the human body and redefining its relationship with technologies. The use of devices such as smartwatches, biometric sensors, and advances in biotechnology is transforming how data not only describes biological phenomena but also shapes identities and cultural practices. This convergence raises questions about how the body is interpreted and represented in a data-mediated environment.

The project *Transmutations: Aesthetic Explorations for the Subjective Signification of Signals and Data* is situated at this intersection, proposing the translation of biological data into meaningful aesthetic experiences. Beyond its informative dimension, it seeks to explore how these signals transform human subjectivities. According to Haraway (1985), the boundaries between the biological, technological, and cultural are porous, opening up new ways of conceiving identity and the body. In this context, the project is framed around three key processes: transduction, translation, and transcription.

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Transduction focuses on the transformation of one form of energy into another, such as when the variability of heart rate is translated into sound changes in rhythm and intensity. This process reveals how technologies not only extend our sensory capabilities but also reconfigure our experience of the world.

Translation transforms numerical data or biometric signals into artistic forms that are understandable, bridging the gap between scientific languages and more poetic or aesthetic ones. This process not only presents biological data as objective information but also re-signifies it by transforming it into visual or auditory narratives that appeal to both emotion and critique. By incorporating an aesthetic dimension, these narratives go beyond their technical nature, fostering an emotional connection that invites the experience of data as something deeply human. Furthermore, this approach could stimulate a more critical reflection on power structures, data hegemony, and their impact on society, broadening their meaning towards ethical, cultural, and subjective dimensions.

Finally, transcription addresses the symbolic materiality of data, inscribing it in cultural media such as textiles, sculptures, or interactive installations. By doing so, data is not only physically recorded but also integrated into space and the body, opening new dimensions of interaction.

The concepts of transduction, translation, and transcription serve as central strategies in the project, though their roles need clarification. Translation refers to the transformation of data into perceptual forms: visual, auditory, or textual, that carry emotional and critical weight. Transduction involves converting biometric rhythms into sound or light, focusing on embodiment and immediacy. Transcription centers on inscribing data into physical objects, like textiles or installations, emphasizing materiality. These strategies, while interconnected, each contribute uniquely to the aesthetic and conceptual exploration of the project. This differentiation helps avoid confusion with terms like “encoding” and clarifies each strategy’s role in the critical and sensory experience.

Other terms we are exploring in the project are:

Encoding: To correctly display characters, the system (computer, webpage, etc.) needs to know which characters to use. These elements can be letters, numbers, punctuation marks, among others. Encoding means changing something from one format to another to make it easier to understand and process. It is going from one domain to another.

Decoding: Decoding is the opposite process. It involves transforming a sequence of symbols into something comprehensible to humans, such as converting encoded data back into letters, words, or numbers that we can read and understand. Again, it is going from one domain to another.

Mapping: Among the encoding and decoding, does a set of rules that establish the relation between domains, a kind of function that allows going from one to the other. This is the place where subjectivity can have an aesthetic and exploratory role (Manovich 2002).

2. Project Description: Transmutations

We live in a society deeply intertwined with data, where companies have integrated data extraction as the central axis of their business models (Peña 2023). This "extreme datafication" of human experience has deep implications, affecting areas such as politics, culture, and even our perception of reality (post-truth). But this scenario also offers opportunities to reinterpret data through aesthetic strategies, enabling individuals to appropriate it in a personal and reflective way.

The project, set to be exhibited between June and July 2025, explores these dynamics through an experimental approach that merges biology and aesthetics, computing and textiles, sound and images. Based on the analysis of genetic data from the artists involved, the project is a reflection on the codification of bodies and subjectivities, in a complex socio-technical system where each interconnected element impacts the others (Pinch et al. 1987).

The process begins with the artists' DNA test data, which is creatively reinterpreted through technological tools and aesthetic decisions, exploiting its symbolic features (Manovich 1999). From this data, three experimental works per artist are generated (image, audio, object), which are then remixed and emitted as radiofrequency signals, symbolically returning the data to the environment.

2.1. Goals

The primary objective of the project is to examine the implications of the current data culture, creating pieces that represent data and signals from the artists' subjectivities. Among its specific objectives, the relevant goals include:

- Developing three communication pieces in each domain (image, sound, object) for each artist, based on their DNA data, using both analog and digital tools.

- Creating a final digital-analog piece that merges the works of both artists, with the parts containing signals later broadcast via radio frequency.
- Generating printed documentation that captures the project's process, along with samples of previous works and reflections from invited writers.
- Presenting this experience through a series of activities, including exhibitions, talks, and workshops.

2.2. Description of the Components

The project uses the artists' DNA data, represented by nucleobase sequences (A, C, T, G), as the foundation for the creation of the works. The number four is used as a pattern, with elements such as colors, and base tones, among other parameters. The works will be developed in three domains: sound, image, and object, and will eventually be transformed into signals emitted via radio frequency.

- DNA Tests: The artists' DNA data (processed through commercial services) will serve as the basis for the project. This data is transcoded into other domains, such as Morse code, numeric, sound, visual, etc, and by doing so explores different ways to be represented. (fig. 1)
- Sound Representations: Each artist will develop sound works exploring the temporal dimension. María José will link the data with structures from traditional weaving and the printing of information onto textiles, while Ricardo will focus on the intersection of biological and economic data (such as the variation of the dollar, for example).
- Visual Representations: Each artist will create visual works that explore the data in two dimensions. María José will use four-color weaving patterns, while Ricardo will investigate images from Chilean and universal paintings, among other possibilities.
- Physical Representations: Both artists will explore data physicalization by using objects or interfaces, such as weaving systems, or installations with old electronic devices, among other possible explorations.
- Radiofrequency Emission: A special construction will be made to facilitate the emission of radiofrequency signals containing the remixed data, creating a symbolic connection with the surrounding environment. (Fig. 2)



Fig. 1. DNA Test: Kit to conduct the test. After being processed, the company sends back the data results in raw format.

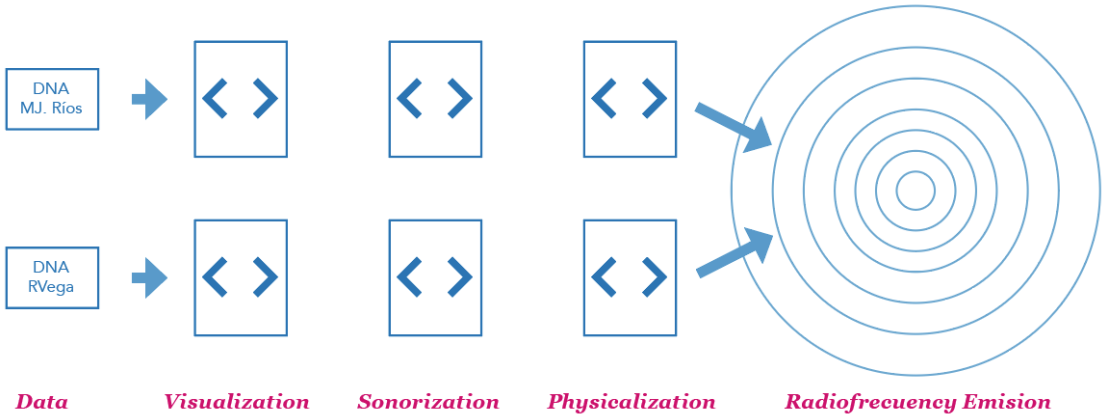


Fig. 2. General Process: Based on biological tests, one for each artist, visualization, sonification, and physical representations of DNA sequences are developed. Finally, the DNA sequence from both artists will be emitted as radiofrequency signals to be defined.

2.3. Technical Aspects and Process Availability

The project will use Python (for data capture, processing, sound, and image creation), Processing (for image and sound creation), and Pure Data and Chuck (for sound creation). Different hardware will be used for physical pieces, such as an old TV. The project also considers a support team to help in the development process. The material (code, images, etc.) will be made publicly available on the internet, allowing others to use the code and develop new versions. The documentation will be made available on a website and GitHub Repository (https://github.com/ricardovv/proyecto_transmutaciones) for open access.

3. Rethinking Identity at the Intersection of the Biological and the Technological

While we are born with a specific set of DNA that specifies our fundamental biological characteristics, this does not dictate an unchangeable fate. DNA provides a genetic foundation influencing our physical and physiological predispositions, but its expression is shaped by external factors. Epigenetics plays a key role here, as Jirtle and Skinner (2007) point out, studying how elements like diet, stress, or social interactions can activate or silence genes without altering the genetic sequence. This shows that while DNA is fixed, its expression is dynamic and can change over a lifetime, influenced by experience and environment.

Donna Haraway, in her essay “A Cyborg Manifesto” (1991), argues that identity cannot be separated from the technologies around us. According to Haraway, there is no clear line between the biological and the technological, as the machines and devices we use are extensions of ourselves. These technologies not only enhance our physical capabilities but also affect our subjectivity, shaping how we understand ourselves and the world around us.

Thus, human identity emerges from the interaction of three forces: biological (our DNA), epigenetic (environmental modifications), and technological (the tools we use). This hybrid view highlights that while we are born with a genetic configuration, our identity is not fully determined by it. Instead, it is shaped by dynamic interactions between genes, environment, and technology. This relationship between biology and the environment, mediated by technology, invites us to rethink identity not as fixed, but as a construct in constant evolution. The innate and the acquired continuously engage in a dialogue, revealing a process where human beings are both products and agents of change in a deeply interconnected world.

4. The Decontextualization of Biological Data

The decontextualization of biological data in the biomedical industry and on commercial platforms presents a significant issue: reducing complex genetic signals to simple units of information. This process disregards the cultural, social, and historical contexts that give biological data meaning, limiting the understanding of identity to utilitarian and commercial views. On these platforms, genetic sequences are simplified into ancestry profiles, presented as abstract percentages that strip away the cultural and historical significance of biological identities. By leaving the interpretation of data to corporations, structural inequalities are perpetuated, excluding communities from constructing and claiming their genetic narratives.

As for María José's textile object, it is inspired by simple, enveloping designs, drawing on both traditional and contemporary sources. The essence of this design lies in the concept of creating a wearable work of art that fuses DNA sequences with textile art. The piece features a woven waistband crafted using Andean-Mapuche techniques, a tribute to the region's deep cultural heritage. The design is influenced by the enveloping and structural style of Issey Miyake, known for his innovative approach to fashion that combines simplicity and functionality. Miyake's work often focuses on creating visually versatile garments using pleats and flexible fabrics that facilitate movement. This influence is reflected in the textile piece, which is not only a visual representation of genetic data but also a functional work that adapts to the shape of the body.

When we consider the artistic use of genetic data, we see that it differs perceptually and conceptually from the use of arbitrary data sources like white noise. Genetic data carries a weight of personal, familial, and cultural history that shapes the audience's experience. These data are not only biologically significant but also imbued with

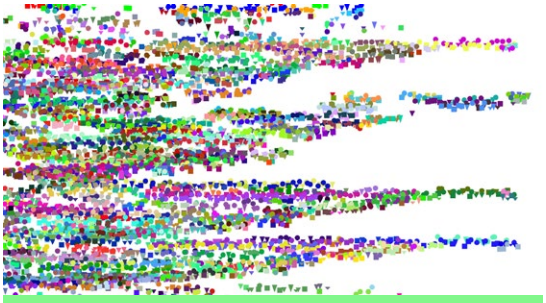


Fig. 3. First visual test of data representation for textile printing, created using Python Colab and Processing (2024).

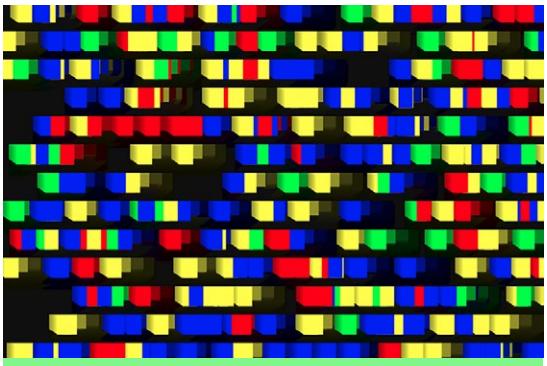


Fig. 4. Second Visual Test of Data for Textile Printing: Based on biological data (2 DNA tests), Visualization of the data based on DNA sequences, created using Python Colab and Processing (2024).

emotional, symbolic, and even political meaning, which is often tied to issues of identity, heritage, and human connection. This gives genetic data a symbolic weight that arbitrary, synthetic data cannot replicate. These perspectives and cultural aspects take the form of metaphors such as the “book of life” (Kay 1999), deeply embedded in cultural imaginaries related to DNA.

The challenge for artists is to transform biological data into aesthetic experiences without reducing it to mere abstraction or commodified categories. In this sense, while commercial platforms reduce DNA to simplified charts for consumer satisfaction, artistic practices must avoid the same pitfall. Without clear answers or theoretical frameworks, attempts to “aestheticize” biological data risk reproducing the very reductionism they aim to critique.

5. Cultural Reinscription and Political Dimensions of Data

The Transmutaciones project proposes an alternative vision for biological data, moving away from technocratic reductionism. The Transmutaciones project challenges this approach by advocating for a cultural and aesthetic recontextualization of genetic data, recognizing it as a dynamic and interpretable subject. At the core of this rethinking is the understanding that data, especially genetic data, are not immutable truths that exist in isolation, but are shaped by the contexts from which they emerge. The project invites us to view biological data as situated constructs, deeply embedded in histories, cultures, and social experiences.

Using different subjective decisions in the process of mapping from data to representation, Transmutaciones highlights how genetic data, far from being neutral or purely scientific, are inextricably linked to political and social processes.

In a broader context, this cultural re-inscription of data brings to the forefront questions about ownership, representation, and the ethics of genetic information. Who owns the data generated by genetic tests, and how can that data be used without erasing the rich histories and metaphors it carries? The project points to the need for a more equitable and transparent approach to the collection, interpretation, and use of biological data in particular, but to any data source in general, inviting to explore different ways to explore representation as a way to re-appropriate data from subjectivity and imagination (Vander Moere 2008).

6. Data as a Critical Tool

From a critical perspective, data are not passive or neutral reflections of the world but actively shape the realities they claim to represent. They are socially constructed artifacts, embedded with the ideologies, exclusions, and priorities of the systems that produce them. As D'Ignazio and Klein assert in Data Feminism, "Data are not objective; they are the product of unequal social relations, and this means that they are saturated with bias, injustice, and structural oppression" (D'Ignazio and Klein 2020, 7). This understanding reframes data not as inert facts, but as discursive instruments capable of legitimizing authority or, conversely, unsettling dominant structures of knowledge.

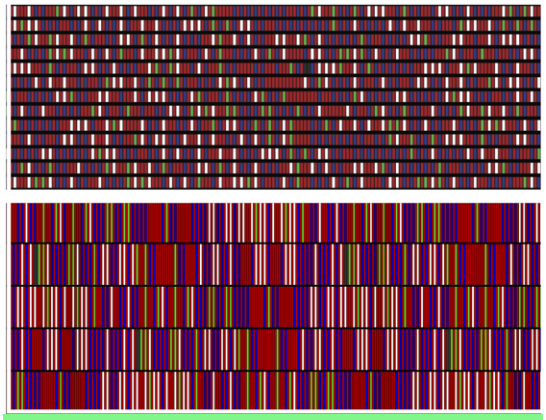


Fig. 5. Visual test of data with audiovisual projection, made using Processing (2024).



Fig. 6. Exhibition layout using 4 old tube televisions that will interact with light pulse triggers from DNA data.

Viewed this way, data become potent critical tools, exposing structural inequalities, serving as raw material for collective political action. When activated through sound, image, movement, or touch, they can transcend their abstract form and catalyze situated responses. Rather than being fixed or final, data becomes open to re-interpretation and embodied encounters. This transforms data from static repositories into relational and affective experiences, becoming triggers for sensing, feeling, and acting.

The translation of data into multisensory experiences, through sound art, installation, or textile interaction, alters how they are received and understood. This multisensory re-articulation democratizes access, breaking away from technocratic codes and inviting diverse audiences into dialogue with the data's meaning. Donna Haraway anticipates this in her notion of situated knowledge: "All knowledge is embodied, situated, and tied to specific contexts of power and experience" (Haraway 1988, 581). Ultimately, the critical and artistic use of data must resist the logic of disembodiment. It must insist that data are never 'from nowhere'; they are always from someone, about someone, and used by someone.

6.1. Co-Production of Meanings

Within this critical and performative framework, data are not passively received or interpreted; instead, they become catalysts for the co-production of meaning. Audiences are not treated as mere observers, but as agents who, through their affective, cognitive, and sensory engagement, contribute to the ongoing interpretation of data. This interaction blurs the boundary between subject and object, positioning meaning as relational and emergent rather than fixed or given.

In collective and participatory contexts, data activate their cultural and political dimensions, no longer functioning solely as information-

al units but as provocations for dialogue and memory. As Karen Barad notes in Meeting the Universe Halfway, “Agency is not restricted to humans; data, like other non-human elements, can reconfigure relationships and meanings” (Barad 2007, 178).

From this perspective, data, like objects, technologies, and materials, possess intra-active agency: their meaning does not preexist the encounter but emerges through entangled relations with human and non-human actors. In artistic, scientific, or hybrid projects, data thus function not as mirrors of reality, but as co-constructors of new imaginaries. They guide decisions, shape interactions, and open up unexpected possibilities for interpretation and transformation.

This entangled model challenges individualistic and anthropocentric notions of meaning-making, proposing instead that subjectivity is always collective, situated, and contingent. Through these processes, data become sites where multiple narratives, knowledge, and agencies intersect. In doing so, they open new epistemological grounds for thinking and feeling the world differently.

6.2. Data as Situated Practice and New Narratives

To reclaim data as critical and transformative tools, it is essential to understand them not as neutral abstractions but as situated practices. Data are generated, interpreted, and mobilized within specific historical, political, and material conditions, and therefore carry the marks of the systems that produce them. Recognizing their situatedness allows us to move beyond the illusion of universality or objectivity, making space for multiple truths, plural epistemologies, and embodied interpretations. When data are abstracted into charts or percentages without context, their power to challenge dominant narratives is neutralized.

Artistic practices, particularly those that engage with visual, sonic, or performative translations of data, offer a powerful means to recontextualize data and generate alternative narratives. This transformation of data into sensory and participatory forms through sound, image, or gesture does more than communicate information differently: it activates new ways of knowing and imagining collectively. As Evelyn Ruppert (2017) points out, data, when critically reconfigured, open up new possibilities for the collective imagination; that is, it is emphasized that data are not endpoints, but starting points for storytelling, and the reimagining of the social fabric.

In this sense, Transmutaciones exemplifies a broader epistemological shift: one that sees data not as static objects to be decoded, but

as living materials, capable of generating new subjectivities. Through the integration of situated knowledge, artistic practice, and multisensory engagement, data become sites of co-creation and political agency, rather than tools of abstraction and control.

7. Transmutaciones (Transmutations) Project as a Hybrid Space

The Transmutaciones project unfolds within a hybrid space where art, technology, and activism intersect, aiming to transform not just data but also to challenge its role in shaping identity and knowledge. As Bishop (2012) suggests, data-driven art does more than just represent reality; it has the potential to reshape it, challenging the way we understand our lives and relationships. Data-based art should not be confined to illustrating information, but can serve as a critical tool to intervene in the social and cultural structures that produce that data. In her work. She emphasizes how artistic practices can generate new forms of knowledge and sensitivity by inviting the audience to engage actively, not merely as recipients, but as co-producers of meaning. This perspective positions art as a symbolic battleground where dominant ways of seeing, feeling, and understanding the world can be unsettled.

The Transmutaciones project emerges as a project that moves beyond the capitalist and technocratic logic that instrumentalizes data for economic or political gain. Instead of viewing biological data as passive inputs for scientific or commercial analysis, the project reinterprets them as active agents capable of generating new relationships and meanings. By transforming genetic patterns into sensory experiences, whether through visualizations, sounds, or movements, these data are re-signified, shifting from abstract numbers to situated, contextualized, and living narratives.

As French theorist Nicolas Bourriaud (1998) suggests, contemporary art can redefine social relationships and create spheres of intersubjectivity that challenge dominant power structures. His concept of relational aesthetics emphasizes that art is not only about producing objects but also about generating encounters and interactions that resist isolation and control.

8. Conclusion

The Transmutaciones project explores the role of data in contemporary culture, transforming it from numbers into vehicles for reflection and tools for transformation. This project proposes a reconfiguration in which genetic data become elements of dialogue, questioning, and aesthetic exploration. As direct participants, we

rethink our relationships with identity and technology, actively engaging in creative processes that re-signify data within a broader and more situated context.

By integrating the aesthetic and cultural dimensions of data, Transmutaciones not only challenges the usual means of representation but also opens possibilities for artistic exploration. Data is presented not as inert statistics but as agents capable of generating changes in our conceptions of knowledge and subjectivity, highlighting the importance of considering the different factors involved in data production.

Furthermore, the project shows that art can go beyond its representational function to act as a critical medium that helps to rethink our relationship with data, now part of our culture as technology is. By exploring data representation and mapping strategies guided by subjectivity, Transmutaciones invites reflection on what it means to be human in the digital era, exploring new ways of constructing and sharing knowledge.

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Operativity: From Images to Archives

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Extending Harun Farocki's concept of "operative images," we introduce the concept of "operative archives," reflecting the profound changes brought about by digital information processing in archiving and beyond, necessitating a reevaluation of image theory. Farocki's "Eye/Machine" trilogy highlights images for automated operations in ma-chine vision systems that replace human aesthetics with machine readability. These images, particularly exemplified by the impersonal precision of guided munitions or automatic facial recognition, are emblematic of the transition towards a system where images are processed and enacted upon by machines. Central to the notion of "opera-tive archives" is the principle that no image stands alone; images are pluralistic, interconnected components of vast data sets that drive automated decision-making and the training of AI algorithms. This collective characteristic of operative images within operative archives challenges the singularity of images and necessitates a collective, systemic understanding. With AI advancement, the impact of these archives on societal structures and individual free-doms becomes more pronounced. The concept of "operative archives," derived from Farocki's work, calls for a new image theory that addresses the societal impacts of such technologies, ensuring ethical and democratic guidance for their evolution and integration into the fabric of society.

1. Harun Farocki's operative images

The digital processing of information has profoundly transformed nearly all aspects of life. Contributing factors to this change include: the combinability and nearly infinite storage of data, their rapid dissemination, and extensive networking, the impact of which we often underestimate despite their ubiquitous presence.

Harun Farocki's trilogy "Eye/Machine" begins with images from the 1991 Iraq war showing so-called "intelligent weapons". Shots of cameras attached directly to the explosive devices and transmitting from there. Farocki refers to such shots, taken from a non-human, yet subjective perspective – that of the missile – as "subjective phantom images" (Farocki 2004, 13). They show surgically clean operations, images without people, full of precision, without emotion. Here the

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camera's images are only a depiction, the documentation of an operation. With "Eye/Machine", Farocki introduces the concept of "operative images", referring to images "that do not represent an object, but rather are part of an operation" (Farocki 2004, 17). These images are distinguished by two key aspects: Firstly, they are not intended for human eyes but are produced by machines for machines. Secondly, they are not representations but rather functions, instructions, or components of operations (cf. Hoel 2018, 26).

Operative images are not meant to be viewed passively or interpreted aesthetically, but rather to be acted upon or interacted with in some way. They are tools for controlling or manipulating reality. Operative images can be found in fields such as medicine, surveillance, industrial or military operations, where their primary function is to act out a task, provide information or facilitate decision-making. By exploring the role of images in different applications, Farocki reveals how images have evolved into potent tools for exercising power in contemporary society. The concept of operative images thus poses significant challenges to traditional image theories, as they cannot be explained or interpreted through established frameworks.

Trevor Paglen says, that in the light of the development of new visual paradigms in warfare, industry and surveillance, for example, the human eye has more and more become an anachronistic tool (Paglen 2014, 1). Similarly, Hoel argues when she writes that "[...] the advent of a new visual regime, and simultaneously of a new stage in the history of machine vision where the machines have started to see for themselves" (Hoel 2018, 12). Though operative images are largely dissociated from humans, no longer created or intended for human perception, human involvement persists in numerous aspects of these images, such as their programming and what algorithms are trained to see in them, in interpretation, and application of their outcomes. Above all, it is humans who are most affected by the consequences of these images. Operative images reference a before-the-picture – the concept, the programming – and an after-the-picture – the result of the execution of the image order. Aspects that are in turn ac-cessible to the human being, determined by her/him.

Nearly two decades after "Eye/Machine" was produced, Farocki's material appears strikingly anachronistic. Both computer simulations and examples of machine vision seem dated, still closely oriented to human perception. Since its inception, the field of operative images has grown steadily and rapidly, and is increasingly linked to the field of machine vision. Thus, Volker Pantenburg refers to the "om-

nipresence of practices such as data mining, image retrieval, facial recognition software and related practices" (Pantenburg 2017, 49) and continues: "Wherever algorithms of pattern recognition are employed, images become part of and merge with a technical operation" (Pantenburg 2017, 49). The term "image" may no longer be appropriate, according to Pantenburg; instead, he suggests that data visualization may be a more accurate term (Pantenburg 2017, 49). The image, he says, has become a "secondary function, almost a gesture of courtesy extended by the machine" (Pantenburg 2017, 49). Although operative images are now pervasive and differ significantly from Farocki's original examples, his conceptualisation and analysis as a distinct category of images prevails.

Farocki analyses the structural composition of operative images as fragmented, discontinuous, impossible to observe, drawing on Vilém Flusser's concept of the technical image: "What defines these images is that they are composite images made up of individual, discrete entities (grain, dots, lines, pixels). More than their concreteness and functional character, they are characterized by their formal composition" (Pantenburg 2017, 52). The difference between these two types of images lies in the fact that the former can be observed, thus enabling a sensory experience, while the latter does not emerge from observation, but from computation (Flusser 2011, 10 and Pantenburg 2017, 52). And such is the operative image: "The operational image is not only a 'working image:' but also an image that is the result of a calculation, as opposed to other forms of image production" (Pantenburg 2017, 52).

Jussi Parikka highlights the historical and intellectual roots of the concept of operative images (Parikka 2023), and emphasizes that they are not only about perception and sensing, but also about operations. He traces the origins of the emphasis on operations back to the field of operational research (OR) that developed in the U.S. and British militaries in the 1930s and 1940s (Parikka 2023). OR involved the quantifiable analysis of military operations for the purpose of optimization, and it evolved into the more speculative systems analysis of the Cold War era. For Parikka, these systems analysis approach can be thought of as "institutional-level 'machine learning systems' that aim to formalize, train, and model based on available quantitative data" (Parikka 2023). This means that learning itself becomes a formalized operation, and the successes of operations research led to the belief that mathematics and theory now have become the superior to more traditional tactics based on experience ways of operating. Parikka's highlights the historical and intellectual roots of the

concept of operative images and the importance of understanding the broader context of operations research and systems analysis in the development of these technologies.

Parikka emphasizes the centrality of numbers and data in the production of images as well as the history of industrialization. He notes that data is not infallible or objective, and that the use of data-driven decisions and operations can have significant social and economic implications, even if the data itself is flawed or incorrect. This means that the use of operative images is not simply a technical or aesthetic issue, but is also an intervention in broader social and cultural landscapes. Parikka's comments become particularly relevant in light of the growing interest in big data, machine learning, and artificial intelligence, all of which rely on the collection and analysis of vast amounts of data. As the use of these technologies has the potential to shape, form and transform social relations and our sys-tems of values in significant ways, it is first and foremost important to recognize these broader implications (Parikka 2023).

In the historical developments "are the implicit conditions of emergence for what Farocki called the 'soft montage' of archive and inconsequential images" (Parikka 2023). This soft montage involves the juxtaposition of archival or found images with inconsequential or seemingly unrelated images. Parikka suggests that the emergence of operative images is an implicit condition for the development of this approach, and that it reflects a wider historical and cultural context in which images are increasingly being shaped by data-driven processes, such as "questions of artificial intelligence and machine vision, but also to the genealogy of the concept of operations as it pertains to images, institutions, spaces, and nonhuman visuality" (Parikka 2023) or what Farocki framed as the "industrialisation of thought" (Farocki 1993 cited after Parikka 2023). A category such as "inconsequential images" is about to cease to exist: every image might be of importance.

Another difference between "conventional" and operative images is the immediacy of their application. Operative images are images that can be used directly to perform specific actions or processes, while conventional images are considered more passive and aesthetic objects. Operative images are often used in industrial, military or surveillance environments where they need to be analyzed and processed in real time or very quickly. While an image in the traditional sense is ambiguous and can be interpreted in several ways, this should be avoided at all costs with operative images; unambiguity is their premise. One example is surveillance cameras that capture subjects and

objects in real time to identify potential threats and trigger alarms. In contrast, conventional images often have a longer lifespan. Duration also plays a role in viewing: while conventional images are passive and people encounter them contemplatively, operative images are triggers for immediate action. They are fundamentally instantaneous and ready for use, especially due to their digital nature (i.e., without prior interpretation, without the need for conversion to another format). Immediacy is reflected, among other things, in real-time use, direct applicability, and direct feedback on an action.

2. Operative images and machine vision

Expanding on Farocki's notion of operative images leads us to contemporary machine vision, employed for example in automated facial recognition and various pattern recognition applications. As operative images, they have become active agents: "Instead of simply representing things in the world, machines and their images began to 'do' things in the world", describes Trevor Paglen (Paglen 2014, 1). This means that their primary function is not to be viewed and understood by humans, but to serve a specific operative purpose carried out by a machine. The perception of these images is closely linked to action, whether immediate or delayed. As a result, "This coupling systematically operationalizes terrains and targets" (Parikka 2023).

Such images are employed across various domains, with military applications being among the first, as Farocki demonstrated. However, they have since extended into everyday life, evident in automated facial recognition and other face-targeting technologies. Machine vision transcends mere image generation by computers for computers; it relies on a vast pool of images for training AI algorithms and result comparison. We argue that these growing sets of images and their fragments constitute speculative archives or arsenals, embodying both individuals and collectives. The images do not exist in isolation, as Roland Meyer remarked (Meyer 2021, 9); they are components of dynamic image networks, serving specific purposes and performing tasks.

Operative images surpass data visualization, as they are grounded in reality, with the real world serving as a basis or reference point for comparison. Their purpose within a complex process is to prompt subsequent actions, rendering them active. These "images" are not final products, but represent stages or triggers for actions justified by their presence, which may be executed by either humans or machines. It is vital to acknowledge that "seeing" has long surpassed being a privilege exclusive to humans or other organisms. Nowadays,

we metaphorically use the term to describe machine vision processes. Here, “seeing” pertains less to sensory experiences and more to the recognition and intricate processing of patterns. Within these processes significant events are programmed, learned by algorithms, and executed. These “images” and this “seeing” directly affect people and their bodies. Trevor Paglen suggests that the rise of operative imagery represents a significant shift in the way we produce, consume, and understand visual information, and that this shift has important implications beyond the purely machinistic for how power and control are exercised in various domains (Paglen 2014, 3). This power is meant to be interpreted literally, “We’ve long known that images can kill. What’s new is that nowadays, they have their fingers on the trigger” (Paglen 2014, 3).

Paglen concludes that “I don’t know how we will learn to see this world of invisible images that pull reality’s levers, but I do know that it’s imperative for other artists to pick up where Farocki left off, lest we plunge even further into the darkness of a world whose images remain invisible, yet control us in ever-more profound ways” (Paglen 2014, 3). We must not stop at knowing that these images exist; we must understand that the concept of the operative image is proliferating and that it is our responsibility to try and understand these images as they continue to evolve and have further impact on our lives, he suggests. Even if they remain hidden from human view, these images have the power to shape reality in profound ways. By referencing Harun Farocki, Paglen also emphasizes the importance of historical and cultural awareness in this process. Farocki believed that artists had a responsibility to critically engage with the visual culture of their time. Paglen’s conclusion can be read as a call to action, urging other artists to follow in Farocki’s footsteps and engage with the challenges posed by operative images in our contemporary moment. Paglen believes that it is imperative for artists in particular to take up the challenge of making the invisible visible and raising awareness of the need for greater transparency and accountability in the use of such imagery.

Farocki scrutinizes the application of operative images in various contexts, particularly their impact on decision-making, actions, and political processes. He underscores the importance of critically examining this class of images to comprehend their social and political ramifications, and to prevent potential misuse. Farocki was deeply committed to highlighting the necessity of devising counter-strategies by exposing concealed images and image processes. He posited that their invisibility and opacity often stem from their use in indus-

trial, military, and other sectors that are typically inaccessible to the public. Through his work, Farocki sought to expose these processes and their societal effects, thereby promoting awareness of these critical issues. For Farocki, revealing these images and processes was the first step towards formulating counter-strategies. A deeper understanding of how these technologies function and their implications enables us to implement appropriate measures to mitigate their adverse effects. An indirect example of a counter-strategy emerging or being inspired by this increased visibility is the digital rights movement, which calls for greater transparency and control in data collection and processing. Additionally, other movements and initiatives champion data protection, freedom of expression, and freedom of information, though the connections should be further substantiated since they are not direct links. Farocki's work aims to raise awareness of image usage and imaging techniques across various domains, thereby helping cultivate critical reflections and counter-strategies to minimize the negative impact of these technologies.

3. Operative archives

This discussion focuses not on the nature of individual images, but on the potential of images in their accumulation, fragmentation, and reconfigurability as both individuals and abstractions. It explores the speculated future, the partially archaeological analysis of the past through artifacts, and the present as a nexus for stocktaking and launching speculations. In conclusion, we want to speculate about the transformative potential of operative images and their role in constituting a new type of archive, the operative archive. This novel form of archive challenges our previous understanding of images and archives, as well as raises critical questions about privacy, individual freedom, and democratic values. We argue that understanding operative archives and reflecting on their potential power is essential for establishing limits and preserving freedoms in the digital age.

Archives debated in this context are to be understood as an extension of Farocki's concept of operative images. These images are also characterized by the fact that they are not to be thought of in the singular, but almost exclusively in the plural. Partly as already existing accumulations, but also as speculative and further accumulations.

Operative archives are archives that are not passive repositories, collections of documents, stakeholders of the unchangeable past, stored accumulations, dead stock, shelf corpses or, as Hertz & Parikka call it, "Zombie Media" (Hertz and Parikka 2012). But they actively intervene in and bring about various processes and control certain

developments. They hold and exercise power in the same way that traditional archives do.

We argue that these images have the potential to do multiple things. These multifolaint potential in combination with their flexibility, their combinatorics (not just relations put potential relations), their storage and transmission is what makes them relevant in the context of a new kind of archive. We need to discuss the term operative image not as a single image, but shift to the accumulation of large image sets, image parts and contextual information, in fact moving away from the image as a complete entity to the image as information that possibly results in an image in the widest sense of the word, in image as a metaphor for what we don't have an adequate concept or term for at the moment. No image exists in isolation (referencing Roland Meyer again); all are interconnected and increasingly interoperate. While traditional archival processes aren't discarded, they have become almost helpless in the face of digital capabilities. Effortlessly, digital technology can assume and transform prior archival activities, functions, and processes, extending them into versatile forms. Information is now operative, meaning it is easily combinable, transferable, storable, and more, whether entirely or in part, and regardless of its current relevance or perceived value. Due to their flexibility, combinatorics, and transmission capabilities, operative images possess multifaceted potential. The abundance of their presence combined with their connectivity, their interconnectedness, their data-ness, their operationality makes these archives a phenomenon to be noted and reflected upon. The image as a whole, its visual components and metadata, becomes information that can and is being exploited, stored indefinitely, traded, and repurposed in many ways not originally intended, with significant implications for privacy, freedom of expression and democratic values. The question thus is not whether these archives will shape our future. As a society, we have to ask ourselves what limits we want to set, what freedoms we want to preserve or create.

The central distinction lies in the operationality, be it active or momentarily dormant or speculative. The ability to utilize information in operations doesn't only enhance the efficiency of known and yet-to-be-imagined operations; it also significantly impacts our lives. We explore this, extending Harun Farocki's definition of the operative image to encompass any digitally accessible or convertible information in this operative sense. Collectively, these data traces create powerful accumulations, akin to historical archives' influence and power, which we will refer to as the speculative form of operative archives.

Operative images are images of the moment. They are not meant to stay, they do. When at first not intended to be permanent, this aspect is changing. They can and are increasingly being stored indefinitely; “trash” is no longer thrown away, but can later prove to become a “golden nugget”. Increasingly, the components of operative images, such as biometric data, facial recognition images, or DNA samples, are stored individually or in combination for long periods of time. As these data are often collected and stored without the knowledge or consent of the individuals concerned, the implications for individual privacy and freedom need to be addressed. The long-term storage and use of operative images impacts how companies, governments, and other organizations make use of them. The same technologies can also be used to identify and classify groups of people and lead to a range of discriminations. The images and their components can be and are also used to monitor, to control, and to manipulate individuals and groups, in particular to identify critics or intimidate political dissenters. Critically accompanying and reflecting on the creation of such operative archives from the very beginning, not only knowing, but also understanding them, is therefore of vital importance for social responsibility and democratic values.

Both “image” and “archive” may not have left their original conceptual yard in this speculative consideration, but they transcend the previous understanding. Both are more than metaphors; they have assumed, or are in the process of assuming, the functions archives once had and were recognized as having. Technologies such as automatic facial recognition and forensic DNA phenotyping (FDP) rely on operative images and contribute to the development of these archives.

It need particularly to be emphasized that in the interplay between private companies, which collect and process this data and offer it as a commodity, and state authorities – especially law enforcement agencies – a new complex of actors enters the field and it has to be asked how the production and use of such data exceeds their legal powers, especially when it comes to data as sensitive as that relating to the human face.

Critically reflecting on the creation of operative archives and understanding the effects of long-term storage is an essential task for preserving social responsibility and democratic values. Operative archives are both in plain sight and hidden from view. As digital data, operative images are tentacular (a term borrowed from Amade M’charek 2020, 370) and adaptophile, allowing for the interconnectedness, operationality, and abundance of their presence. It is crucial to note and reflect upon these operative archives, as they will inevita-

bly shape our future and already affect our presence. As a society, we must consider the limits we want to set and the freedoms we want to preserve or create.

Operative archives affect the perception and construction of realities. They can be used to perform and produce both individuals and groups. These archives represent power in a very direct way, as they can influence the way people make sense of events and phenomena, reinforcing or suppressing certain narratives and perspectives. They already actively intervene in and bring about various processes, controlling certain developments rather than merely serving as passive repositories. As they accumulate and store images for specific purposes as well as unspecific ones, as they continuously grow and become more complex, concerns about potential misuse, social control, and surveillance arise. It is important to highlight the particular relevance of data relating to the human body. Operative archives based on images of people and their associated metadata are transformed into permanent data bodies, which can act in their entirety, in parts, or as cumulative data bodies. Especially in the context of training algorithms for AI, metadata play a crucial role. Without them, there is nothing to learn. It is through the metadata accompanying the images that artificial intelligence can make sense of and derive meaningful insights from these operative archives.

To further discuss operative archives, it will be important to consider:

- The role of algorithms and artificial intelligence is critical in the creation, analysis, and manipulation of operative images. They significantly contribute to the formation and functioning of operative archives. Through the examination of extensive data sets, AI systems can discern patterns and make predictions with unparalleled efficiency. However, this reliance on algorithms and AI raises concerns about the potential biases and inaccuracies inherent in these technologies. For example, if the training data used to develop an AI system is biased, the system itself may perpetuate and amplify these biases, leading to misrepresentations, misinterpretations, or even discrimination.

- Legal and regulatory frameworks that govern the collection, storage, and use of operative images and data also play a crucial role in shaping the operative archives. Existing legislation may not adequately address the unique challenges posed by these new technologies and the huge amounts of data they generate. As a result, there may be a need for new laws and regulations that specifically address issues related to operative images and ar-

chives, ensuring that individual rights and freedoms are protected in the digital age.

- The ethical responsibilities of those who create, maintain, and utilize operative archives, including private companies, governments, and researchers have to be reflected. These actors must recognize the potential consequences of their actions and strive to develop and implement best practices that prioritize transparency, accountability, and respect for individual privacy and autonomy. By doing so, they can help ensure that operative archives are used responsibly and ethically, minimizing potential harm and fostering a more just and democratic society.

Extending on Farocki, it is therefore important to be aware of this speculative form of archiving, to know and understand operative archives, and to become aware of their potential power, to reflect on them critically, and to ensure that they are transparent, accessible, and democratically controlled.

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Challenging Disability and Interaction Norms in XR: Cooling Down the Empathy Machine in Waiting for Hands

Virtual Reality (VR) is often hailed as the "ultimate empathy machine," framing disability as an experience to be simulated through such technologies—reducing disability to a spectacle of pity or inspiration. In response, we present *Waiting for Hands* (WfH), an interactive eXtended Reality (XR) installation that critiques this logic by: (1) Repurposing interaction norms in XR by building Alternative Controllers, and (2) Staging an absurd XR performance experienced using the built controllers to disrupt the sentimentalized disability narratives. The XR performance involves eight persons: two XR participants on stage and six seated audience members who watch a projected documentary about Hema Kumari, an Indian singer living with Rheumatoid Arthritis. The XR users' partially obscure the film, diverting audience attention through strange mouth and hand movements (instructed to perform in XR), creating a dual-layered experience that disrupts active viewership in Hema's story and introduces uncertainty. While XR is considered as a hot medium—fully immersive and sensory-dominant—this piece subverts that rationale by repurposing XR to produce absurdity and *alienation effect*. By defying empathetic, hence pitiable narratives of disability, we reflect: what ethical stance an XR performance can take to attune participants to a non-normative body schema while resisting spectacle?

1. Introduction: Motivation and Background

We are witnessing a significant transformation in how bodies interact with technologies in space, as the Internet overflows with videos of people wearing XR headsets in public—making "hand-gestures'' in mid-air while ordering at Starbucks, pinching fingers while crossing streets, and performing expansive 360-degree body movements to interact with these devices. XR (or eXtended Reality), an umbrella term for Virtual/Mixed Reality (VR/MR) technologies are proliferating, what Apple is referring to as the dawn of a new era in "spatial" computing. Meta (formerly Facebook) calls this the "next evolution in social connection", *The Metaverse*, which the company claims, "will be built by everyone, [...] by all sorts of imaginative people." Yet, this vision of inclusivity excludes many, for example, our collaborator Hema

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Kumari, an Indian disabled artist, singer, and activist who lives with RA (Rheumatoid Arthritis). Hema's arthritis limits how her body can move in space and the hand gestures she can perform as any bodily movement is accompanied by elongated pain —particularly while using the hand-based XR controllers. Hema's inability to use XR technologies highlights how Big Tech companies reinforce ableist norms, informing what HCI researchers Gerling and Spiel (2021) call a "corporeal standard" in XR design—a template of a non-disabled body as the default user. Mott et al. (2020) likewise claim that the dominant XR devices are designed with "ability assumptions" (Wobbrock et al. 2011) hindering people with sensorimotor disabilities to access such technologies "when their abilities do not match these assumptions". Jain (2024) similarly critiques the implicit biases in XR technologies, demonstrating how they can be re-purposed, hacked and modified by drawing on lived experiences of disability.

In our proposed XR artwork, *Waiting for Hands* (WfH), we interrogate the interaction norms in XR alongside Hema by rejecting hand-based interaction as the default. Instead, we integrate Alternative Controllers[1] into the XR setup as a way to hack the very technologies under critique. The interface employed is a camera-based mouth and lip tracker (integrable in XR), co-developed with and for individuals with disabilities. This tool has been utilized by the authors in their previous artworks and is aligned with the same line of inquiry in *WfH*, as elaborated below.

In this case and context, the mouth is a key body part that Hema relies on for her everyday activities when her hands and legs are in tremendous pain. That is, her arthritis compels her to find new affordances—what disability scholar Arseli Dokumaci calls 'activist affordances': "possibilities of action that are almost too remote and therefore unlikely to be perceived and yet are perceived and actualized through great ingenuity and effort to ensure survival". (2023). In other words, "the tiny, everyday artful battles of disabled people for more livable worlds that otherwise remain unaccounted for." (Dokumaci 2023). These include Hema's act of using her teeth (instead of hands) to pull blankets over herself during winters, unscrewing water bottle caps by gripping them between her teeth and squeezing lemons by pressing them in her mouth. These tasks inform Hema story about how hand movements encompass the possibility of pain, and how the situated intelligence of the body shifts toward the mouth—all the acts that motivated the framework for the XR performance. Hence, leading to the design of Alternative Controllers, a mouth-based assistive interface to interact and navi-

gate in XR, putting the mouth at the forefront in the XR performance, *Waiting for Hands* (WfH).

Concretely, our aim is to, firstly, expose the ableist biases embedded in the XR systems (i.e. revealing the mandatory use of hands in XR is an ableist assumption) and in return reshape the engagement of the audience in the performance (by shifting to mouth as a means of interaction but also distraction). The XR performance involves eight persons: two XR participants on stage and six seated audience members who watch a projected documentary about Hema. The XR users' partially obscure the film, diverting audience attention through strange mouth and hand movements (instructed to perform in XR, see Figure 1). That is, the audience watching Hema's story is not simply "transported" into her world; rather, they must contend with the disruptions caused by the alternative mouth-based interaction in XR. We create an open-ended and fragmented experience that requires the audience to actively negotiate meaning and reflect on what they are witnessing. By introducing friction through absurdity and the *alienation effect* (Verfremdungseffekt[2]) achieved in the performance design and setup, we "cool down" the "immersion" of these XR devices. We leverage assistive technologies to cultivate an alternative that centers the mouth and shifts the gaze away from objectifying Hema or portraying her disability as something to be pitied. Instead, the gazed is direct towards the assumptions of 'able-bodiedness' embedded in standard interaction design. However, it is worth noting that this project is not about making technology "more inclusive" in the way accessibility is often understood—adding accommodations as a gatekeeper to an existing paradigm. Instead, we propose rethinking the storytelling itself, one that enables reclamation for Hema and her life story of living with RA with the very [XR] technologies that marginalize them. Such stories, when told, as disabled queer femme of color educator-scholar Shayda Kafai argues "uncovers and gives voice to those who are unseen, marginalized, and forgotten," embracing "Disability Justice and its principle of collective liberation" (Kafai 2021). Taking this into consideration, our positionality is one of refusal—pushing back against the extractive logics of the voyeuristic gaze that reinforce ableist narratives. We want to resist perception of disability as spectacle, drawing inspiration from a rejection of the reductive framing of XR as an "empathy machine" (Milk 2015)—a concept that risks reinforcing disability as pitiable through empathy.



Fig. 1. Two participants on stage interacting with hands and mouth in XR.

Hema's Video Documentary plays behind them.

This proposal builds upon the prior experience of the authors in creating XR artworks and performances using Alternative Controllers as input modalities within XR systems. Concretely, *Waiting for Hands* draws on two research-creation projects: (1) First project explored a taxonomy of "disabled" mouth-gestures in XR detected by an assistive camera-based interface, developed with and for disabled artists and activists Eric Desrosiers and Christian Bayerlein (Jain and Salter 2025). These mouth gestures enabled the artists, Eric and Christian, to move and interact in VR/MR environments through chin, jaw, and tongue movements and were later realized as artistic strategies incorporated into the XR artwork *Crip Sensorama* (Jain, Bayerlein, and Duarte 2024) (2) The second project involved the development of custom wearable interfaces for *Pinch to Awaken XR* (Duarte and Rodriguez 2025), an XR performance that integrates DIY bio-sensing technologies with XR to explore body-technology relationships through the tracking of breathing patterns. A hybrid performer guides the audience through a digital/tangible performance, engaging them in a narrative that encourages synchronized breathing with a responsive environment, ultimately fostering bodily self-awareness. *WfH* extends this lineage of experimentation, proposing an interactive XR performance that not only questions dominant narratives around disability in XR but also reimagines how technology can attune to diverse bodies rather than demanding that bodies conform to technology.

2. Theoretical Framework

WfH explores how storytelling in XR can move beyond normative expectations toward a disability-centered perspective. We embrace Disability Justice as a framework that emphasizes with the idea of collective liberation. These concepts inform our design by shifting the focus away from a deficit model of disability and toward a more

inclusive, resistance-based approach that centers disabled experiences in XR spaces. Our approach is inspired by what disability scholar Margaret Price (2024) calls *Crip spacetime*: "a material-discursive reality experienced by disabled people... whose meaning is made through the relations among words, bodies, objects, technologies, and environments." We aim to apply these ideas to reimagine spaces of XR by integrating nontraditional yet accessible interaction modalities through "assistive" XR—shifting away from ableist norms in spatial computing towards a more inclusive *Crip spacetime* framework for all.

Additionally, we also draw from radical theatre traditions to further inform our design approach: Brecht's Epic Theatre and Beckett's Theatre of the Absurd (Brecht 1964, Beckett 1953). Although these approaches differ in method and intention, both share an interest in questioning human existence and disrupting audience expectations. From Beckett, we inherit a dramaturgy of uncertainty, absurdity, and existential stasis. His plays—marked by repetition, silence, disjointed time, and non-sequiturs—reject linear progression and resist resolution, emphasizing instead the instability of meaning and the precarity of human experience. In *Waiting for Godot* (1953), for instance, time loops and non-action foreground the absurdities of waiting and dependency, conditions often pathologized within ableist frameworks. From Brecht, we draw on the *Verfremdungseffekt* or alienation effect, a technique designed to break the illusion of realism and encourage audiences to question what they see rather than passively consume it. Brecht sought to politicize theatre by making spectators aware of its constructed nature—through direct address, visible stagecraft, and episodic structure. *WfH* applies this principle by making the XR interfaces itself visible and "strange", using alternative or assistive controllers.

Extending these principles into XR, we engage with McLuhan's (1964) concept of hot and cool media, in relation to the level of engagement and interpretation those demand from the audience. XR typically functions as a hot medium—fully immersive, dictating the sensory experience, and fostering total absorption. Moreover, the reference of XR as "ultimate empathy machines" (Ventura et al. 2020, Hassan 2020), as the technologies that can enable one "to step into others' shoes" through simulations, has popularized these technologies as tools that can foster "positive attitudes" towards disabled communities (Chowdhury et al. 2019). This technological affordance has led to a growing trend of XR simulations designed to "feel" disability, such as experiences of blindness (Silverman 2015), schizophrenia (Penn,

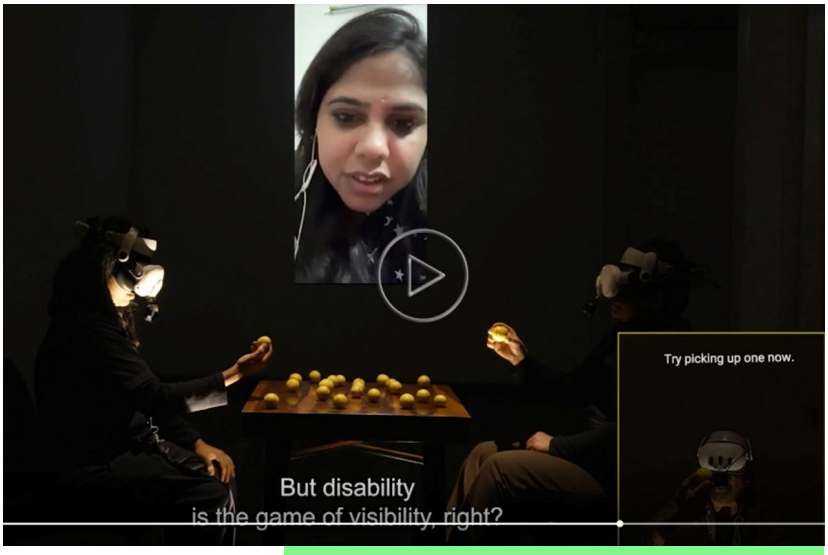


Fig. 2. Video documentation of the premiere exhibition at Khoj.

(https://tinyurl.com/wfh-videodocumentation).

Ivory, and Judge 2010), and even migraine (Excedrin 2023). Although these simulations claim, "to foster empathy and increase disability awareness, they often fall short of these goals, reinforcing harmful ableist attitudes." (Nario-Redmond and Gospodinov 2024).

This approach is problematic and has been especially critiqued in disability studies, due to simplifying complex social issues into temporary states and its tendency "to emphasize impairment-related deficits and dependence rather than the social, economic, and environmental factors that contribute to the challenges disabled people face." (Ibid 2024). The risk is perpetuating the notion that disability is merely a deficit to be overcome (medical model), rather than a diverse mode of being in the world (social model). Through the convergence of *Crip spacetime*, radical theatre, and media theory, we disrupt XR empathy machine to attune audience bodies to a shared narrative of disability culture and lived experience—one that resists spectacle, challenges normative embodiment, and reimagines interactive spaces.

3. Performance Description

Exhibit as a work-in-progress, *WfH* is an 8-minute performance, an interactive experience for eight participants: six seated audience members in a default theatrical setup, while two members are invited onto the stage, each wearing a XR headset adapted with a mouth and face tracker. The experience differs for each group.

The seated audience watches a video projection on a stage wall (see Figure 1), entering the world of Hema, a disabled artist based in Delhi, India. Meanwhile, the two XR participants, seated between the projection and the audience, face each other across a table. Immersed in an XR experience, they interact using their hands and mouth—first separately, then collaboratively, and ultimately engage with the seat-



Fig. 3. XR participants on stage holding lemons while watching the seated audience in passthrough.

ed audience through physical objects. The performance is structured into two acts, separated by a two-minute interval (See Figure 2 and Link for Video Documentation). In Act One, the video introduces Hema's life and artistic practice. The seated audience watches as her story unfolds, while the two XR participants experience a scene centered around lemons. Initially, XR participants use their hands to pick floating virtual lemons, but as the experience progresses, their interactions shift to mouth-based controls, navigating a surreal highway, surrounded by lemons. As the first half of the documentary ends, a plaque announces the interval, and the curtains close.

Act Two begins when the curtains reopen, revealing the table now covered with real lemons (see Figure 3). Hema reappears on screen, directly addressing the seated audience about her disability. Inside XR, the participants' interaction also shifts—this time, they pick up tangible, material lemons. The passthrough function (RBG cameras in the XR devices allowing users to see the material world through it) activates mixed reality, allowing them to see each other. Following a series of guided instructions, XR participants engage with the lemons in unexpected ways, eventually extending their actions to the seated audience (see Figure 4). As the seated audience members interact with XR participants, Hema appears on the screen singing a Bollywood folk song and the performance reaches its conclusion.

This setup allows us to explore not only new possibilities for storytelling of disability life and culture but also the potential for an artwork that hacks and disrupts contemporary VR/MR technologies. Through this absurd performance, we steer the audience away from affective immersion that reduces disability to simplistic emotional responses. The two XR participants disrupt the dominant paradigm of hand-based interaction in XR by using their mouths as primary interfaces, exposing how XR technologies assume certain bodily norms.



Fig. 4. Participants in XR interacting with the members of the audience, offering them lemons.

Within the performance, the XR devices function as Brechtian "distancing devices", disrupting default expectations and transforming interaction into a mechanism of critical reflection. This shift forces the audience to navigate between the two narratives: what is being shown (Hema's story) and what is being enacted (the XR interaction). This intentional displacement resists the objectification of the disability tourism, creating friction that prompts questions in the audience: What should we focus on? Should we empathize with Hema's story? Should they decode the XR interaction? How do these elements connect? What are the two participants doing? What are we watching? Why are they throwing material 'real' lemons to the audience?

These "unreliable actors" are active agents, which provoke and mislead by mediating possible meanings and distorting perspective. At times, reinterpreting Hema's gestures from the video, connecting it with XR participants actions—creating an ambiguous relationship between the visual and the embodied. This acts as a distancing mechanism, challenging conventional audience expectations and resisting the sentimentalization of disabled bodies. *WfH*, thus poses the following key question: How can an XR performance challenge the power dynamics embedded in current human-machine interfaces? What ethical stance can such a performance adopt to attune participants' senses to a non-normative body schema while resisting the voyeuristic gaze and the sentimentalization of disability? In turn, how can this attunement expose the deep-rooted prejudices shaping our perceptions of bodies, space, and XR technology?

4. Conclusion

Waiting for Hands stands at the intersection of *Crip spacetime*, radical theatre, and media theory, using XR to attune audience bodies to a shared narrative of disability culture and lived experience—one that resists spectacle, challenges normative embodiment, and reimagi-

nes interactive spaces. By foregrounding mouth gestures as primary inputs in XR, the performance disrupts the assumed hierarchies of bodily interaction in XR, expanding the boundaries of what we are accustomed to experiencing in immersive environments.

Beyond expanding interaction modalities, the work intervenes in broader XR discourses by critically engaging with the ableist assumptions embedded in spatial computing. It challenges the industry's prevailing reliance on hand-based interactions and the 'empathy machine' narrative, proposing instead an XR that fosters active negotiation of meaning rather than passive consumption of experience. Through its approach, *WfH* reveals how accessibility can be a generative force for innovation in immersive media, rather than an afterthought. By questioning who XR is designed for and how it encodes normative assumptions about bodies and abilities, this work calls for a radical reimagining of interaction design—one that embraces diversity. As the field of XR continues to evolve and devices proliferate, *WfH* demonstrates that accessibility is not an act of objectification but a reflective space—one that challenges assumptions and pushes the field toward more inclusive and innovative futures.

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Notes

+ indicates equal contributions.

1. "Alt Ctrl" are physical input mechanisms for interactive media that are distinct from traditional console-affiliated handheld controllers or computer inputs such as mice and keyboards. (Shake That Button n.d.)

2. Verfremdungseffekt (or "alienation effect") is a theatrical technique that disrupts the audience's emotional immersion to promote critical reflection on the play's social and political themes (Brecht 1964).

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What is Algorithmic Pattern? Reflections on a Salon

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The emerging research theme *algorithmic pattern* is introduced, as bringing together people from a range of fields, including a wide range of cultural and theoretical backgrounds, to define a new interdisciplinary field. This is done in the context of the Algorithmic Pattern Salon in late 2023, considering both contributions and surveys of participants taken before and after the event. We work towards defining the central algorithmic pattern term, to help build a collective understanding of the theme. The different aspects of algorithmic pattern form primary interrelated themes: abstraction, material behaviours, human culture of pattern making, and patterns in nature. Commonalities and differences between practices are considered towards developing language for discussing them on equal terms, and opening spaces for experimentation between them.

1. Introduction

Algorithmic pattern is an emerging research theme that explores the intersection of procedural logic and material practices, encompassing the ways that algorithms interact with embodied, hands-on pattern-making traditions. It brings together people from a range of fields including algorithmic choreography, live coding in performing arts, design computation, and experimental textiles/fibre arts. As such, algorithmic pattern is a space where such people are coming together to define a new interdisciplinary field. The words *algorithm* and *pattern* are brought together as being on one hand largely synonymous, standing for a procedural, systems-based approach to creativity, but on the other hand having very different senses in popular use. This intersection opens up ways of thinking that address computation not only as abstract and digital, but also physical, historical and cultural—blurring these boundaries (Griffiths et al. 2023).

Although patterns are found in creative disciplines throughout history, and across cultures, the use of the term pattern as synonymous with algorithm in the context of computing technologies and creative practices (Dourish 2016, Spiegel 2018) generates new meanings and ways of doing that dialogue with their ancient roots. Patterns are used, committed to memory, recognized and distorted, rotated,

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transformed etc. with creative purposes but rather than abstract entities they interact with the materials of their various implementations.

Practices such as knitting patterns, weaving block designs and juggling site-swap patterns, for example, although perhaps viewed as distant from digital computation, embody algorithmic thinking in physical, embodied forms (McLean 2020). They notate discrete, numerical procedures and are therefore themselves digital and computational. These practices reveal how algorithmic systems can emerge in culturally embedded ways. This framing grounds algorithmic pattern in lived experience and tradition. Thus, this research asks "what is algorithmic pattern" in the context of practices using algorithmic pattern-making as a way to generate material.

The word *algorithm* stands for a sense of corporate, coercive control such as the hidden hand behind 'algorithmic timelines' in social media, or the unfathomable complexity of large language models. The word *pattern* has a perhaps more humane sense of patterns in hands-on craft; procedural knitting patterns, weaving block designs, and so on — what Audrey G. Bennett refers to as *heritage algorithms* (Bennett 2016). These contrasting associations offer a productive tension with which to explore how algorithms and patterns both converge and diverge in practice. Rather than positioning these as in opposition to each other, we acknowledge the potential of algorithmic pattern research practice to interrogate and potentially reframe them.

As a theme of research and practice then, algorithmic pattern seems well placed to connect people from a wide range of cultural and theoretical backgrounds, to try to establish a humane approach to creativity with algorithms, as a way to survive the 'AI summer' by connecting heritage and contemporary pattern-making technology, and better ground our understanding of what should happen next. With this motivation in hand, we still need to define what an algorithmic pattern actually is. There is a 'boot-strapping' problem here; as an interdisciplinary community, such a field should define its own terms, but does not yet fully exist. To resolve this, we created space for the community to come together and start to define itself, as the algorithmic pattern salon.

2. Algorithmic Pattern Salon

The salon took place over five days, spread between 23rd November and 1st Dec 2023. It brought people together to share and discuss algorithmic approaches to pattern-making in creative arts, craft and code. We are writing some time after the salon, using the opportunity to reflect on what went on, before our next event in September 2025. Because the salon was in part convened to help define what we might

mean by the term algorithmic pattern, it did not address a fixed theme, but began the process of building a community of researchers and practitioners to create one. Already, the algorithmic pattern framing helped us to separate computation from the specific realms of machines and codes. Yes, they are there too, but the term helps surface likenesses to a broader range of embodied, cultural, historically rich traditions. In some ways, it brings context to code and enriches our understandings (and thus future visions) for computation in society — algorithmic pattern points to a long history, not just one that emerges with industrial automation and silicon-based computing.

The following brings together the defining themes that emerged through the salon, and participants' takes on the concept of algorithmic pattern.

2.1. Communities of Practice

People have creatively explored algorithms as patterns together across millennia, working with diverse materials, developing procedures to extend their collective imaginations, and developing practices and communities around them. Such procedures may provide a defamiliarising force, as a means to arrive somewhere not purely driven by intention. As such, the creative domains under which the remit of algorithmic pattern falls are extensive, diverse and transdisciplinary; notions of pattern run through the fields of textiles, choreography, mathematics, music, design, and the visual arts, to name but a few. Each may have varied understanding, informed through entangled (Frauenberger 2019, Nordmoen and McPherson 2022) and situational knowledge (Haraway 1988, 2016) that informs the practice. For example, within textiles, one might view algorithmic instructions for knitting a sock as a "knitting pattern", but also once the sock is knitted, will observe the pattern as a construct that is both perceptual and conceptual, through its visual symmetries, presence/absence of repetition, and physical behaviours.

Patterns are also seen in contemporary computing, from the binary operations involved in low-level machine code, to high-level operations used by creative coders. However, the word *pattern* is overloaded, often used to describe simple phenomena such as straightforward sequences in music. On the other hand, as mentioned earlier the word *algorithm* is often used to describe unfathomable complexity. In combination, *algorithmic pattern* refers to human-made algorithms, where complex and surprising results can result from the combination of simple parts or rules. This offers us rich ways of making, that are easy to learn but may take a lifetime to explore.

As salon organisers, we brought together our own prior experiences working at the boundary of algorithms and patterns linking heritage and contemporary contexts, for example developing craft grammars for transmitting algorithms of wire bending in the Trinidad and Tobago Carnival (Noel 2015, 2020), introducing algorithmic musicians to the heritage algorithms in tablet weaving (Griffiths et al. 2023), generating continuous kolam line drawings and integrating them in textiles (Reddy and McLean 2024), and making pattern-based programming environments for weavers (Friske et al. 2019) and musicians (McLean 2014).

This salon itself brought people together with deep curiosity for patterns. The scope of submissions covered the following topics: architecture, music, performing arts, visual arts, textiles, human movement, mathematics and coding, and many intersections of these domains. By creating space for these communities to interact, we hoped that cross-pollination of understandings might form new insights and build pathways between less-explored conceptual framings.

2.2. Structuring Participation

The participants of the algorithmic pattern salon spanned geography, domains of practice, and professional association or otherwise. The open call invited perspectives to be held on equal ground during the symposium. For example, a PhD student might present their research studying new forms of notation for a textile craft, followed immediately by a video of jugglers enacting manoeuvres based on numeric sequences. As organisers, we found this to be a refreshing shift from the more codified and exclusive formats provided by professional and academic conferences. In some ways, it felt like a possible new path forward for collective sharing and community development that side-stepped the messy politics and exclusivity mandated by certain professional organisations. The presentations and discussions resonated with a spirit of generosity and mutual connection that emerged from a shared passion and interest in pattern, notation, algorithm and embodied experience.

This interdisciplinary spirit is prerequisite to defining algorithmic pattern as a field of practice and research, and so in a sense, forms part of its definition. We have observed that pattern-based practices traditionally take place within community groups, and perhaps as a result are often self-segregated, for example with heavy gender, ethnicity and/or class biases. Trying to work against these biases is challenging, where respect must be given to all the cultural contexts and histories at play. We hope algorithmic pattern can be common ground

for exploring these issues, and for creating space for new creative coalitions to grow inspired by these histories.

3. Defining Algorithmic Pattern

After the salon was completed, we looked to the participants of the salon to help build a collective understanding of the idea of algorithmic pattern, rather than an individualist perspective, drawing on Gergen's definition: "Knowledge is not something that people possess in their heads, but rather, something that people do together" (Gergen 1985, 270). People and groups create knowledge by negotiating the meanings of words, actions, situations, and material artefacts. They all participate in and contribute to a world which is socially and culturally structured and constantly reconstituted by the activities of all those who belong to it (Gherardi 2008). These ideas align with those expressed in the exocerebrum hypothesis, proposed by Bartra (2014), that suggests thinking is a combination of processes that occur inside and outside the skull, when our thoughts are shared with others. Cultural symbols, and symbolic systems are completed when they are put in relation to others' ideas. As such, we wanted to mediate meaning through collective knowledge from participants' reflections.

Before the salon, a questionnaire was sent to all registered attendees, asking them to share a definition of algorithmic pattern, from their own vantage point. A similar approach is employed in Live Coding: A User's manual (Blackwell et al. 2022), where members of the live coding community provided a diverse range of definitions of live coding: a practice that across domains, cultures and knowledges means different things to different people. Likewise, the open-ended question was given to the participants: "How would you define what an 'algorithmic pattern' is? No wrong answers!"

After gathering the results of the participants' individual responses, we looked for ways to draw out common viewpoints. A thematic analysis was conducted on the responses from participants according to Clarke and Braun (2017). Themes were coded with an inductive approach, where there were no prescribed frameworks for analytic preconceptions, but rather themes were left to emerge through repetitions of key concepts.

3.1. Pattern as culture, behaviour and abstraction

From the thematic analysis, we found that the different aspects of algorithmic pattern can be grouped into three primary interrelated themes. The first theme is that pattern-making involves abstraction,

generally in terms of notated procedures for making, although these procedures may also be passed on via oral tradition. These abstractions may be arrived at through playful experimentation, or potentially reasoned about as mathematical or computer scientific constructs of geometry, data structures, models and representations.

Crucially though, these abstractions result in our second theme; real-world, material behaviours. Such behaviours are often surprising, as a feature of the deterministic yet chaotic nature of the pattern-making algorithms at play, and/or with the rich physical properties and constraints of the particular medium that the pattern is working within, whether primarily material (such as textile) or temporal (such as music). In this, human perception is foregrounded and given a creative role in interpreting or perhaps finding new patterns in the behaviour. This can include the perception of interferences, deviations, glitches and errors relative to a perceived underlying pattern. As behaviour, pattern isn't just in the notation, the algorithm in motion, the material results, or our perception of those results, but in the combination of these elements as a whole.

Our third and final core theme is the human culture of pattern making, that is, the arts, crafts, musical, social and political context in which a pattern operates. This is where creation and perception of pattern becomes meaningful, whether through ritual, sharing, collaboration, decoration, trade, or the collective rhythmic entrainment of making or dancing together. This culture develops through generations, being passed on as heritage but continuing to develop, adapting to changing socio-political conditions, such as acts of colonialism and resistance.

An additional fourth theme relates to patterns in nature and geology, where patterns arise through processes such as growth, without human involvement. This is a huge and rich topic in its own right, but runs separately from our focus on human pattern making through notational and algorithmic practices. Nonetheless, patterns in nature often are involved with or inspire the abstractions, behaviours and cultures of human pattern-making, so this distinction is far from clear-cut. We also acknowledge the problems of defining nature itself, and considering ourselves as separate from it.

3.2. Commonalities and differences between practices

A challenge for any interdisciplinary community is developing understanding of each other's practices, through developing language for discussing them on equal terms. This is a particular challenge for us, as the very idea of a 'pattern' may be a core obsession in some

cultures (e.g. textiles, mathematics), while being an ambivalent or pejorative term in some others (e.g. classical music composition).[1] This work needs to establish commonalities and differences between them, reaching understanding of the trade-offs at play, and identifying the limitations of each practice. Here *limitation* is not pejorative; we see that creativity in pattern-making thrives by exploring, pushing against and at times beyond limits.

3.2.1. Pattern in creative feedback

One commonality or difference is where pattern is placed in a creative 'workflow'. Where there is an abstraction, such as a notated pattern function or procedure, this might precede an outcome, in telling how a pattern will be made. Alternatively, it may follow an outcome, in recording how a pattern was made. Perhaps things are most interesting where paradoxically, the notated pattern both precedes and follows the patterned outcome. That is, the notation is the interface for the outcome, where it is first made as speculation, followed through to one outcome, and then adjusted in response to that conclusion, to a new outcome.

In this way, the pattern-maker follows their patterned notation and material, to an outcome well beyond their imagination. According to Tim Ingold, this following of material is a given, in that all making is "[...] a matter of finding the grain of the world's becoming and following its course." (Ingold 2011). Perhaps then this is a commonality for all those now finding each other in the algorithmic field. A weaver dreams up a block design from an experimental configuration of shafts and tie-ups, tries it out in practice, and returns to adjust their notation in response, perhaps to explore interesting interactions happening in areas with unbound floating threads. A juggler tries a complex site-swap pattern, and adjusts it to find a more practical rhythm. A live coder continually adjusts their code in response to the music generated by it.

3.2.2. Material constraints

Different practices are marked by the materials and apparatuses they centre around. These materials set the rules, as much as rules are applied to them.

- Weaving - loom creating tension of warp, which weft is passed over and under. These “overs” and “unders” are dictated by a draft, a set of binary instructions that set a framework for action which, in forms of weaving that are not fully automated, invite the weaver to interpret (e.g. for instance, in practices of inlay; Searles 1984). The weaver may form part of the loom, for example a back-strap loom, where tension is provided by the body.
- Siteswap juggling - throws notated as time durations, measured in discrete ‘beats’, where in solo juggling an odd number passes from one hand to the other, and an even number throws and catches a ball with a single hand (Polster 2002).
- ‘ET’ drumming notation - a technique introduced by drummer Jaki Leibeziet (Podmore 2020), with a binary dot-dash notation as with morse code. A dot denoted a single strike, and a dash a double strike (with one hand). Rules of dynamics follow, where playing a dash with one hand gives more time for the other hand to lift and therefore hit the drum with greater force, producing an accent.

These examples of pattern-making with fiber, movement and sound respectively, are all characterised by rules that follow from physical constraints, which create rich spaces of possibility for artists to explore. All three feature discrete symbols - the up-down counts of a 2/3 twill weave or ones and zeros of a binary grid for weaving, the throw counts of juggling siteswap, the binary dots and dashes of ET notation. What happens when we take some numbers used in one practice, and use them to create patterns in another? What if we juggle a weaving pattern, drum a juggling pattern, or weave a drum pattern? Almost always, the results fall apart, or are too simple or arbitrary. The materials at play are intrinsic to the notation’s meaning.

During the Algorithmic Pattern Salon the physical constraints of the materials and apparatuses appeared in the discussion of the computational constraints for the computational render of high period examples of the Mandelbrot set (Heiland-Allen 2023). When describing the process of weaving incorporating “the shifting of weight on the bench, the creaking of the loom, the rhythm of breath, the pauses for cups of tea, background chatter, and silent contemplation.” It was pointed out that

the result and the time needed for weaving depends on these elements (Wood 2023). These experiences align with the idea that "weaving connects the physical materiality of the woven patterns with their immaterial algorithmic descriptions" (Griffiths et al. 2023), creating a space where unanticipated results happen that can be explored creatively.

4. Reflection

Research events are often considered simply as venues to share outcomes and network. However, above we have looked to capture and reflect upon the actual work of meaning-making that took place at the algorithmic pattern salon itself. As organisers we do not consider ourselves neutral in the process; by making space for things to happen (and indeed forming the selection committee for proposals), we drew on our diverse experiences to create potential for outcomes. However, our aim was to create a space rich enough for unanticipated outcomes, and it was the participants who brought the process to life and saw it through.

In this paper we have explored the commonalities and differences between the practices that arose, considering that a challenge for any interdisciplinary community is developing understanding of each others' practices, through developing language for discussing them on equal terms. This analysis focused on understanding the trade-offs at play, and identifying the limitations of each practice. These common points not only allow us to understand the different practices through a common language but also reveal spaces for experimentation that are intrinsic to the practices themselves.

Two commonalities appeared across the different themes: creative feedback and material constraints. Creative feedback refers to a 'workflow' where there is a notated abstraction that might precede an outcome, in telling how a pattern will be made. An interesting space for experimentation appears when the notated pattern both precedes and follows the patterned outcome, this is, notation is the interface for the outcome, where it is first made as speculation, followed to one outcome, and then adjusted in response to that conclusion, to a new outcome. Perhaps we are following this same pattern in reflecting on the salon, ahead of planning our next event in the series.[2] A call for proposals is like a notation for proposing a pattern of thinking, and we write our next call in response to the patterns of activity that followed it, and flowed into each other during the salon itself.

Regarding material and apparatus constraints that come together with the "physical implementations" of the pattern abstractions, they are all characterised by rules that follow from the physical con-

straints at play, which create rich spaces of possibility for artists to explore as they define the practical actions that come into play. These actions not only define the practice itself but represent the most basic language through which it is possible to experiment in creative ways.

We grouped the different aspects of algorithmic pattern practices into primary interrelated themes: abstraction, material behaviours, human culture of pattern making, and patterns in nature. These themes are present across a wide range of practices and function as recurring elements, whether they are employed as a source of creative material, a framework for structuring design processes, or fundamental principles that guide the materialisation of the practice. We focussed on the first three of these themes, in order to centre human engagement with computation and material. Right now, this focus on human action feels important, reframing algorithms in terms of human agency, and sidelining the notion of algorithms as completely autonomous agents.[3]

Our focus on human algorithms is currently unfashionable, when so much attention is on large language models, artificial intelligence, and autonomy. We are mindful here of Ursula Franklin's description of the continual shift in the "real world of technology" (Franklin 1999) seen in the past decades, from holistic technologies supporting human activity through work, to prescriptive technologies of control. Alan Jacobs supports Franklin's and similar perspectives which he groups as the "Standard Critique of Technology" (Jacobs 2021), while also pointing out that rather than restating this critique of the dominant technological paradigm, we should demonstrate alternatives in order to make a real difference. This is where we hope algorithmic pattern comes in - as a field of research and practice where we reflect on holistic (Franklin 1999), convivial (Illich 2001) technologies from the past and present, to try to create a new future, building upon and inspired by them.

Notes

1. Andrew Hugill noted differences in understanding pattern in a discussion with mathematicians, designers and western classical composers in his May 2013 presentation "Establishing Transdisciplinary Entities in Universities, or: why is it that musicians make the best interdisciplinarians?", available at https://medias.ircam.fr/x6e2d95.

2. Our next event will be Algorithmic Pattern 2025, a full conference and festival taking place in September 2025. https://2025.algorithmicpattern.org/.

3. We do not dismiss the potential for AI language models, and do support and engage with movements around explainable, responsible and ethical AI, but are here centering other approaches to human creativity through algorithms

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Algorithms and Environmental Concerns: From Game Design to Creative Resistance

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Recent design projects critically explore the social deployment of algorithmic technologies in relation to pressing environmental concerns. This article analyses a selection of projects that explore more activist and investigative possibilities. Examples include games based on current climate models, workshops exploring alternative blockchain systems for food justice, and occupations targeting the expansion of tech industries. These projects are analyzed for the way they accommodate diverse strands of eco-literacy and activist awareness. It highlights how design can make use of interventionist tactics and contribute to social investigations. The paper contributes to the developing design criticism to guide (design) research towards actively countering the current devastating environmental impact of new technologies.

1. Introduction: environmental concerns, technology, design

When designers get to work with digital technologies, ecological and social issues will have to be addressed and critically investigated. The digital world has been exposed as costing the earth (Pitron 2023) and technological innovations of the last decades have negatively impacted ecologies and environments on a global scale (Cubitt 2017). More specifically, current applications of artificial intelligence have far reaching social, material and ecological consequences (Crawford 2021) so there is a need for rigorous scrutinizing of such technologies when aiming for any kind of more sustainable future (Dauverge 2020). The inherent abstraction, extraction and solutionism of the current complex techno-social systems reinforce “hegemonic approaches and necropolitical tendencies” (McQuillan 2022, 100). Countering this is a complex challenge only to be addressed collectively. Designers have to somehow navigate the current frenzy of accumulation, extraction, circulation, transport, global impacts, and also the “numbing conformity with the precepts and regulations of a system we know to be malign” (Crary 2022, 118).

Only by avoiding structures that promote inequality, epistemic violence, capitalist exploitation and environmental destruction, design can be offering possibilities to be part of, and support, ways of living

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beyond the error embedded in the current political system (Mareis and Paim 2021, 11). The gateway to structural renewal is “cooperative, horizontal, and non-coercive” resistance (McQuillan 2022, 147). Designers then need to develop such resistance, specifically against the systemic, persistent, ongoing forms of oppression under the “matrix of domination” which design so far often ends up reinforcing (Costanza-Chock 2020, 123) for example by working on adaptation, mitigation, or negotiation (Lamb et al. 2020). It also means opposing innovations and reforms which conform to the existing social logic and capitalist economics (Gelderloos 2022) as in the form of green capitalism in which “complex, ethically and socially fraught, and inherently political questions presented by ecological crisis” are transformed “from democratically contestable terrain to the private authority of markets, with outcomes ultimately driven by the self-interest of rational actors motivated by profit” (Buller 2022, 274). Designers will have to address “historically naive, imperialist views” (Staudenmeier 2022) and counter the vast arsenal of denial, fraud and misinformation surrounding environmental problems and technology (Delay 2024). Design today struggles to acknowledge the complex interplay of such mutually reinforcing social determinants and dynamics of power and privilege (Mareis and Paim 2021, 13).

Based on such critical perspectives, the question arises how design can meaningfully engage with the development of algorithmic technologies and the related ecological concerns in such a way that it fosters social resistance and investigate ways towards structural alternatives. Expanding designers’ eco-literacy and engaging with activist cultures are proposed as necessary to such efforts, as is the experimentation with more interventionist tactics. Specific reference projects are analysed as encompassing cases to better understand of this variegated contemporary field of creative investigation, which amounts to the development of a specific design critique for this type of creative work.

2. Developing design criticism

Design criticism has been asking questions for decades about the relationship between design and, for example, climate change and global warming, often already in relation to new technological developments (Twemlow 2017). Design criticism is precisely how to discuss and evaluate creative efforts and design choices in relation to such broader concerns and developments, and to determine additional directions for creative exploration for the design profession or design education. The focus of design criticism is on concrete design projects, which makes it into a heuristic and practical tool which

can keep the focus on concrete experimenting (Fischer and Riechers 2019). Analyzing specific (design) cases contributes to recognizing the stakes and map the contingencies of the developed creative work (Fox et al. 2020). Although sometimes operationalized through more limited 'design critique methods' (Alabood et al. 2023) design criticism can be elaborated towards a form of social critique for design (Petrina 2017) or critical fabulation around the history and possible futures of design (Rosner 2018). By criticizing, it can challenge the design discipline, for example calling out for redesigning design (Anastassakis 2021) or contributing to what can be called disciplinary disobedience (Abdullah 2021). Such more broad and challenging criticism is developed below in relation to recent creative efforts engaging with new technologies and environmental concerns.

2.1. Beyond discursive and critical design

The kind of creative projects that this design criticism focusses on are those that materialize some form of (design activist) counter-narrative (Fuad-Luke 2009). Such projects, more recently labeled discursive design, are made to work in opposition to or outside the usual commercial paradigm and instead offer 'intellectual prostheses' in the form of objects created and deployed with "the primary goal of affecting thinking about big, complicated, or contested issues" (Tharp and Tharp 2018, 8). This type of design practice stems from earlier critical and speculative design approaches that focused on problem finding and provocation in the service of society, most notably developed and theorized by Dunne and Raby (2013). It is also informed by adversarial design which puts emphasis on enabling productive contestation and dissensus (DiSalvo 2012). Alltogether it constitutes a rich contemporary field of creative exporation for designers, especially when it incorporates artistic activist unhinging of usual ways of doing and thinking that embrace more experimental branches of political thought (Simoniti 2023). Recently, however, it has also been criticised for the abstract and ambiguous material practices it results in (Mareis et al. 2022) and the "fleeting experimental vision" it presents mostly at galleries or exhibitions (Simoniti 2023, 152). It is often produced in safe environments and risks offering only a passive affirmation of design, even to the point of fetishizing critique (Keshavarz 2019). In the following, design criticism is developed that aims to point towards and suggests opportunities to explore more provocative and bold directions beyond or in addition to the more regular critical and discursive design practices.

2.2. Eco-literacy and laboratories of learning

According to Boehnert in her seminal work on designs engagement with ecology and politics (2018) for such more bold projects designers will have to adopt an activist awareness of current dynamics that perpetuate 'oppression, exploitation and ecocide'. This awareness is necessary for re-orienting the inherent politics of design towards explicitly embedding matters of care and processes of activation in the design process (Huybrechts et al. 2022). To do so, Boehnert suggested designers can make use of ideas like permaculture, social ecology, eco-socialism, food sovereignty, indigeneity or ecofeminism (Boehnert 2018). Such eco-literacy is not only necessary to come to systemic understandings of current dispersed networks and structures (Capra and Luisi 2014) but it is also fundamental to (re)direct critical design skills to engage with for example decolonial practices and alternative imaginations (Buck 2019). Only through such concepts it is possible to address the more structural aspects and root causes of climate change and propose alternative structurally transformative and systemic pathways for change (Morrison et al. 2022). For this paper we will analyse creative projects that explicitly develop such activist awareness through engaging with radical concepts of eco-literacy, to better understand how this is currently done or might be expanded.

Design can be understood as offering tools and spaces for collective exploration and actioning (Fuad-Luke 2009). In relation to new technologies and ecological concerns this can take the form of 'climate investigations' (CIC 2017), mapping of power (Dávila 2019), and creative forms of counter-forensics (Fuller and Weizman 2021). As such it can be more elaborative than just producing discursive objects, initiate "an ongoing reflexive dialogue, through making and use" for experimenting "with different histories and imaginaries" that enhances positive subversion and conversion (Leach and Wilson 2014, 242) that for example merge current academic research on more-than-human perspectives, regenerative approaches and AI, systems thinking and alternative (design) pedagogies (Poikolainen Rosén et al. 2025). Although always being at risk of academic institutionalization as part of the global knowledge economy (Holert 2020) it could take part in the development of (technological) infrastructural experiments (Vickers et al. 2020) that are integrating research and societal challenges as a lab for the public (Introna et al. 2024). As such design seems to work towards engaging in forms of 'social investigation' (CounterPower 2020, 18) where radical thought and practice form a nexus through which radically alternatives can emerge (Thatcher & Dalton 2022, 33).

Design and activism can then be inspiring eachother (Bieling 2019) as for example happens in the mutual shaping of data practices and social movements (Treré 2022). Design could be understood as a way for mobilizing and prefiguring what has recently been called social movements' experiential laboratories of learning (Novelli et al. 2024). As grassroots networks of locally resisting communities realize promising responses to climate emergency and planetary destruction (Gelderloos 2022), design might want to find ways to genuinely participate in these social ecosystems of revolt and the ecological imaginations found there. After analysing creative projects below, the current ways such social investigation and possible participation in laboratories for learning will be discussed.

2.3. Interventionist tactics

More courageous experimentation and commitment might furthermore be developed by keeping a focus on, and explicitly take as design goal, the creation of interventions. Design interventions can be adopted to improve system thinking and help deal with "wicked issues" (Rygh et al. 2014). Design can make use of multiple concrete points of leverage, for example intervening in subsidies and taxes, gaining access to information, challenging the general mindset or paradigm, or even better, combining an "ecosystem of tactics" for devising interventions (Meadows 1999). By insisting this type of design should be aimed at interventions, it can make use of previous experimentation with interventionist tactics that have been used within art, and which already contributed tools, documented actions and tactics of disruption for socially engaged artists and other collectives (Thompson and Sholette, 2004). A rich tradition of 'tactical media' emphasized the possibilities of experimental media for such interventions (Raley 2009) which is echoed today in the wish for media tools that can decolonize, redistribute value, and conspire (Lovink 2022). Not wanting to rehearse here the "academic debates about short-term tactics versus strategic sustainability, and artistic instrumentality versus aesthetic value", interventionism is predominantly understood here as developing experimental platforms for discourse and research-based practices for exploring conscious political resistance (Sholette 2017, 230). As designers work in this direction, they might be able to construct future spaces and (media) practices for imagining other worlds (Aikens and Crowley 2022). It might open the design discipline to intervention-oriented insurgent practices of subaltern ecological movements and the complementing militant and engaged forms of research including counterhegemonic practices of alllience and solidarity (Undisciplined Environments Collective,

2024). Analysing the type of intervention or kind of interventionist tactis thus seems a promising lens to discuss recent mord bold creative investigation.

By developing design criticism that points at more radical forms of eco-literacy and interventionist tactics, this paper responds to a recent call to catalogue and evaluate (creative) interventions and strengthen these by “drawing together demonstration projects, more experimental designs and interdisciplinary perspectives” (Morrison et al. 2022). In the face of the hegemonic approaches and necropolitical tendencies of current malign techno-social systems, as described in the introduction, such better understanding of more committed and courageous experimentation and social investigation could prove essential for the field of design and beyond.

3. Analysing contemporary (design) projects

Four cases were chosen that were developed over the last years, that are well documented, and stand out in their different ways they engage with eco-literacy and activist cultures, building collaborations for social investigation towards possibilities for intervention. The cases are furthermore selected for the diverse materialisations and media used, corresponding to different subdomains or disciplines like game design, educational design, digital design, or architecture, to accommodate a great variety of practices and examples. The first case takes the ‘Half Earth Socialism’ game from 2022 as starting point and relates this to other recent developments within game simulations and critical forms of collective play. As second case the Algorithmic Food Justice workshops of 2019 was chosen, which is a more situated and embodied type of codesign or ‘commons in design’ project. The third case is the Solar Protocol platform developed in 2022 that relates to the design of different infrastructures and platforms based on alternative socio-technical principles, and finally the protest architecture of the ZAD de Notre-Dame-des-Landes, coming to prominence in 2018, is selected as a multifaceted and encompassing case that builds on earlier instances of occupation and (protest) architecture. This makes a broad and rich set of contemporary creative work to help understand how social resistance and investigation are currently deployed towards the development of algorithmic technologies and the related ecological concerns.

3.1. Half Earth Socialism and related game simulations

Half Earth Socialism (https://play.half.earth/) is a ‘planetary crisis planning game’ developed and designed by Francis Tseng and Son La Pham. The game simulates the effect of different changes in policy

and developments of technologies on the general ecological and environmental situation of the earth. In the game, different governance measures can be taken, like a change in energy production or the development of an alternative food industry. The game options are visualized as a deck of cards which can be “scanned”. Disrupting events can occur, like for example a flood, a forest that gets infested, or the return of a direct-action group called ‘Earth Liberation Front’. Political capital can be exhausted, different government factions develop throughout the game. It shows statistics for temperature, land use, population, and for example average habitability. Through all this, it is possible to play out different governance strategies, experiment with effects of for example alternative global infrastructures or biofuels. The options in the game are not restricted to actual political programs or predefined ideologies, so players can experiment with their own chosen combinations of new educational programs, the development of specific crops, or adopt policies like completely banning meat production. The game calculates emissions and different ratings using a real open-source climate model HECTOR, to work out the climate effects but also the state of the food system, the biodiversity, the general contentedness, and more, in cycles of years. To win you must keep people content and keep your political power, while getting to a world where global warming stays below 1°C, extinction rate is less then 20%, and emissions will have to return below 0, for which you have a maximum of 60 years.

Tseng discussed (2022) the design of the game at Trust, a platform for creatives, as being part of a lineage of scientifically accurate games from Crawford’s 1990 game ‘balance of the planet’ to the more recent Fate of the World from 2011 by the game studio Red Redemption. These politically aware and intentional games can be described as interventions that help understand the existing political dynamics at play and political actors involved (Vervoort et al. 2022), which in the game can be experimented with, but which also remains not totally predictable (Arroyo 2017). Like in the sophisticated art installation Asunder (https://asunder.earth/) made by Tega Brain, Julian Oliver and Bengt Sjölén there is a benefit in taking actual data, models, currently used technologies, which can then help underscore how these intelligent systems and actual data might lead up to “absurd outcomes” and help to actually probe state-of-the-art climate and environmental simulation technology (V2 2024). For Half Earth Socialism, Tseng developed a web tool early in the development process, so other people could contribute content like these cards and events, and collectively research estimate effects of policies or technologies. Central for this are the so-called IAM’s (Integrated As-

sessment Models) used, that make it possible to do predictions and tinkering with outcomes of specific choices within the game. Recently also a new editor mode was introduced in the game that allows you to modify different parameters of the game-model which might lead to a more open setup of game possibilities and outcomes. As such it can function as a conscious subversive practice tool (Flanagan 2009) especially when developed towards “critical metagaming practices” in the form of playful strategic appropriation for resistance (Beke et al. 2024). Focussing on game and simulations, these projects stress there is ‘everything to play for’ in relation to the current power relations and undermining of ingenuity (Did 2024).

The game now seems to promote a specific top down global (future) government strategy. It accompanies the book ‘Half Earth Socialism’ which sketches a theoretical framework that explicitly stresses the necessity for global planning tools and global authorities. The book urged the public and its representatives to work on blueprints, socialist planning, and climate modelling for an eco-socialist future, which in the game should be taken up as planetary measures made through GosplanT, a central planning authority in power. The companying book was criticized for “its narrowing of the alternatives it faces, and its wider refusal to engage with conviviality, decolonization, and the agrarian question” concluding that it leads “ecosocialists down a frustrating dead end” (James and Johnson 2022). Similar critiques on playable models and systemizations of earth through design science recently came up in relation to the exhibition “Terra. Designing our Planet” at Mudac (Kugler and Longfellow 2023). Longfellow attacks the idea of ‘total design’ or the ‘technophile ecological approach’ of Benjamin Bratton as instances of a planetary “earth systems” approach based on an inherent deceptive solutionism on a global scale, ultimately stems from colonial logics. The designer of the Half Earth Socialism game made clear alternative, more local ecosystems to stave of ecological collapse were considered as relevant future iterations to be developed in games, discussing options like a more regional approach with more radical democratic processes (Tseng 2022).

3.2. Situated and embodied local solutions

In comparison with Half Earth Socialism and similar game simulations, a different type of creative practice aims to bring people and other lifeforms that are too often marginalized by design towards actual situated and experimental, hands-on and inclusive design efforts. In extention to more simple notions of co-design or participation (Cizek and Uricchio 2022) these projects are characterized by the fostering

of different social relations (Escobar 2018) through a determination to support liveliness and resilience through what is called “commons in design” (Schranz 2023). It tries to bring decision-making back in the hands of under-represented or assailed communities and spaces (Diehm 2022). It sees opportunities to move away from “malls and computers” instead looking for what can be understood as a “revival in imagination, self-knowledge and connection with animals, rivers, mountains, and trees” (Dunlap 2024, 197).

As an example, the Algorithmic Food Justice workshops by Sara Heitlinger, Lara Houston and Alex Taylor consisted of a bottom up, embodied and situated approach for developing a more-than-human value system for sustaining food commons (Algorithmic Food Justice 2019). Three workshops were organized by City University of London, in partnership with Spitalfields City Farm, Furtherfield, and Gaia Foundation, to experiment with food production that is “sustainably managed for collective benefit” and which recognizing all types of organisms and relations involved. Several small-scale urban farmers and collectives were brought together to brainstorm different (future) stakeholders, mapping resources, and to prototype and experiment through Live Action Role Playing (LARP). It included the creative development of rituals and assemblies, the design of certain card sets, instructions, and risk matrices. The third workshop focused on blockchain technology and DAO’s, experimenting with related “algorithmic methods for valuing and exchanging labor between multiple species in the process of growing food” (Algorithmic Food Justice 2019). During the workshop future follow-ups were discussed like “bacterial festivals, cross-species work placements, holidays for micro-organisms, piloting multispecies communications working groups”. New technologies are reluctantly approached here as mainly “tools that crush divergence and nuance” especially when taken up by designers that continue to create “under the auspices of design thinking, user personas and so-called “ethical design practice”.

It experiments with collectively investigative forms of resistance that takes cues from new technologies but only to improvise completely new relations and economical systems. As Massumi argues the aim of it could then be to become a driver of resistance, beyond more simple commons-centered, collective, collaborative models, and feeding off the dominant capitalist economy, awaiting a tipping point to be reached where the alter-economic way would be capable of taking over” (Massumi 2018, 124). It is related to other initiatives that focus on rethinking the (local) economic dimensions, like Arango Orozco from Grupo Semillas explained, “in a way that departs from

voracious and destructive economic models" and looks for alternatives that prevent irreversible effects on the environment and create a more balanced relationship with the territory (Arsanios 2022). New technological developments here are counterintuitively used to spark undisciplined practices focusing on hands-on engagement and disobedient action research, that could lead to "locally produced experimentation, practice and refinement to create socioeconomically justified and liberated spaces" (Snelting 2022).

3.2. Low-tech affirmative refusal

This focus on local experimentation and hands-on engagement can also lead to different technological infrastructures that work as "a countermodel to the current platform(ed) perception, where everything is served effortless at the nearest screen, hiding infrastructures, carbon pollution and exploitation of data" reconsidering the everyday infrastructures we often take for granted (Pold and Andersen 2022, 110). A prime example proposed here is the 'naturally intelligent network' of the Solar Protocol project (https://solarprotocol.net/) developed from 2022 onwards, which consists of a website hosted across a network of solar powered servers and technology to make this website available to you from whichever server receives most sunshine at the moment you access it. The Solar Protocol website shows how this works, transparently communicating its own functioning and the power remaining for that specific server and stating the constituent principles. The website offers a manifesto that calls for a shift from artificial intelligence to natural intelligence and imagination that is not tied to fossil fuels and to work within natural limitations. It consists of documentation, including technical specifications and guides, to make your own server and become part of this network. The website offers inspiration for additional creative exploration of a more patient, contemplative, and localized relationship with technology, data-visualizations of the network, poetry generators, video works, low bandwidth gaming, all presented and discussed during a 'sun thinking' exhibition. Inspiration for Solar Protocol website comes from the website of Low Tech Magazine (https://solar.lowtechmagazine.com) which for example also applied this way of thinking to a downsized transport network (De Decker 2023).

Additional theoretical underpinning of this kind of projects allow for diverse visions on what computing or technology might be used for, as for example there are convivial computing, benign computing, salvage computing, small tech, appropriate technology or slow-tech (De Valk 2022), or approaches based on degrowth and 'computing within limits' (Roscam Abbing 2021) and permacomputing (https://perma-

computing.net/). Such approaches refute the 'current data spectacle' (Thatcher and Dalton 2022, 84) and refuse to get trapped in structures that seem unchanging and self-replicating, instead opting for "making otherwise" (Voss 2024, 64). It can be understood as a type of refusal that works as affirmation and repair more than denial: a redirection to ideas otherwise unacknowledged or unquestioned, as recently has been theorized in relation to the anticolonial work done in the Civic Laboratory for Environmental Action Research, for which also other useful questions around possible methodologies and protocols were posed (Liboiron 2024, 142). Design makes use here of a type of refusal that usually takes shape in conditions of precarity, domination, and escape (Agid 2020), but the development of such countermodels has ambitions for global scale and planetary impacts when these decentralized alternatives are expanded on through "mutualist and decommodified" cooperation for reskilling, recomposing, and rethinking (Ray 2024).

3.3. Protest architecture

In order to challenge the dominant systems, any alternative has to find ways to actively disarm, power down, abolish, possibly create social antagonism, or actively engage in careful political conflict and clashing (Ray 2024). In the face of climate collapse, it might for example be necessary to overpower and stop corporations which are key players in the theft of the commons (Whyte 2020). The fourth and final type of intervention can be distinguished through such efforts to push back against all kinds of destructive dynamics (Brand and Wissen 2021, 189) and to disrupt the usual "extractive infrastructures and the administrations that enforce them" (Dunlap 2024, 198). It consists of creative efforts that are envisioned to directly challenge and disrupt existing power relations (Camfield 2022, 73) up to possibly sabotaging or dismantling existing systems (Voss 2024, 180). Although every such disruption and sabotaging can also promote repression and become a catalyst for the system's incessant need for more devaluation and capitalist expansionism (Ploeger 2022) the creative work done in this direction is over the last years more often seen as necessary to creatively stop devastating projects from happening, carrying the opportunity to finally direct the world into a different course and save lives (Étienne 2024, 53) and an "injection of collective empowerment" (Malm 2021, 161).

The creative work done at the ZAD (Zone d'Aménagement Différé, that became Zone à Défendre) de Notre-Dame-des-Landes in France could serve as a encompassing example – where a range of protests, buildings, events, rituals, including the necessary new relationships

and learning sessions, were created in what actually amounted to a new kind of (temporary) society that came to exist after the occupation of an airport from the 2010s onward (Fremeaux and Jordan 2021). Where the 'airwold is a smooth and seamless transit between substitutable spaces' the occupants insisted on the "perpetuation of the possibilities of common life that place-based social relations can create, even amidst a striking diversity of beliefs" by an eclectic and diverse group of people "not foot-soldiers to a pre-existing theory or revolutionary prediction but the flesh, blood and thought of the movements they are making" (Mauvaise Troupe Collective 2018). Organization relied on information and exchange tools, like the Zad News newspaper and Radio Klaxon pirate radio (Mauvaise Troupe Collective 2018, 112) and imagination did not remain just 'dreams' but houses were built in the image of the way life outside the norms and the moulds, actually inhabiting these territories (Mauvaise Troupe Collective 2018, 122), furthermore sharing tools, exchanging food, envisioning new collective structures for living and defending. It culminated in huge protests and defensive actions in 2018. There is a rich global history of such protest movements and different types of struggles against what can be summarized as 'land grabbing', where global corporations and governments are countered in their grabbing, commodification and consumption of space and resources (Ross 2014). A recent example that explicitly engaged with the high-tech industry was the mobilization against Tesla's expansion of its Gigafactory in Grünheide's forest (near Berlin) by groups such as the Grünheide Citizens' Initiative, the "Turn Tesla off" alliance, and other organizations and action groups like Fridays for Future. From March 2024 onwards people occupied the adjacent forest, creating tree top houses, involving the residents of the area, culminating in large scale action days organized by Disrupt, an alliance including 'Ende gelände' which is known for earlier occupations and large-scale protests. Together they protested "car capitalism in a green guise" including the neocolonial supply chains, felling of trees and destruction of forests, water usage of 1.8 million cubic meters a year, and more general the proliferation of individual transport in the face of the evolving climate catastrophe (Disrupt 2024).

It is taken up within the field of art and design by stipulating the creative work involved. This consists of festivals, treehouses, pavilions, but also barricades and tripods, which are taken to constitute a broad range of 'protest architecture' also encompassing more satirical materials and subversive tools. It is recently elaborated through a list of accompanying design principles (around for example originality, repeatability, comfort, 'spiciness') and example student work (Newman

2024). Protest Architecture's goal is to blockade, defend, seize space, produce resistance – which scales up to design of complete camps for global movements, of which a recent art exhibition recaptured an already impressive history (Elser et al. 2023). This history of blocking, stopping, destroying and occupying industries' devastating infrastructures or planned extensions and land grab also includes clothing, demonstration material, digital media, graffiti, places for assembly, projections, manuals, protest songs, protection shields, all of which currently received attention as somehow necessary and relevant forms of creative practice (Flood 2014).

4. Current design experiments and the developed criticism

In contrast to how technological innovations have already for decades negatively impacted ecology and natural environments, indeed also diverse forms of creative experimentation have been developed over the last years. Four specific cases served here as example projects that vehemently try to resist and search alternative creative approaches to and uses of the application and development of algorithmic technologies in the face of acute ecological and environmental concerns. Through such projects, as was proposed based on recent literature, designers can be able to steer away from and counter more passive discursive design projects, or any green capitalist solutions, adaptation, mitigation, and negotiation, or further involvement in extraction and solutionism.

The cases were selected to show how eco-literacy and activist sensibilities can be incorporated in design projects by strengethening engagement with more radical aspects of eco-literacy. Half Earth Socialism accommodates all kinds of concepts and actual activist cultures in the scenarios and cards, which can be applied and experimented with in the game, which are the result of a collective investigative research on what these concepts and scenarios actually mean or could set in motion. The Algorithmic Food Justice workshops deal with eco-literacy and activist sensibilities to experiment with nurturing different relations or collaborations, leading up to and underpinning LARP sessions and creative workshops. Eco-literacy is also essential for the accompanying manifesto's to the Solar Protocol project and the contributing theories on for example slow-tech, degrowth or computing within limits. Eco-literacy and activism furthermore inform the rituals, camps, and direct actions at the ZAD or Disrupt actions. These cases thus present diverse examples for nurturing more radical eco-literacy within and through design.

The cases also provide a set of options to creatively challenge and disrupt of existing power relations, for example by thinking through and simulating alternative governance strategies (through game simulations or LARPs), local economies and collaborative tools (through food workshops and low-tech solutions), and active sabotage and occupate land (protest architecture, blockades). It amounts to multiple creative ways to experiment with points of leverage, whether it are climate data models, policies, infrastructures, or the land use of devastating industries. Creating design interventions like this consists of making games, card sets, attributes, matrices, solar panel powered servers, protocols, rituals, festivals, manuals, houses, clothing, protection, and much more, and as such offers diverse opportunities for the design of all kinds of artefacts and 'things'.

By bringing these diverse projects together some preliminary directions can be distinguished for how design can indeed be able to take part in social investigation to push towards engagement with more radical eco-literacy and concrete interventions. It shows ways to invite others to join the experiments, and stimulate self-organization and creative development of alternative infrastructures for exchange. While these cases are part of certain art and design platforms (for example Trust) or exhibitions (for example about protest architectures) they are reaching outside and beyond these, and thereby show ways designers are already traversing and expanding the traditional design discipline and break out of the safe 'design' environments and the passive affirmations of design described in literature. They involve communities and groups outside the institutional settings and art and design disciplines, for example by realizing a game that can be played and updated by a much broader public, invite and empower decision-making of local food cooperatives, or investigate forms of architecture in relation to ongoing struggle by activists occupying land, and make their work available for others to take on. This is the way the here presented design related projects currently reorients towards political activation and the actual fostering of different social relations, in the form of embodied and situated experimentation building towards more liveliness and resilience, inviting in underrepresented and assailed communities, and through countering hidden pollution and destructive effects of technological infrastructures.

By analyzing and relating these projects, and contrasting them to complementary theory, design critique is developed that can focus creative efforts on possibilities for social investigation and contributing actual systemic interventions. For this, the focus of that criticism was on bringing projects in relation to eachother, and presenting

them together as a rich field of creative resistance and experimentation. These cases are furthermore supplemented with for example anticolonial affirmative refusal and other critical theory not usually encountered in design criticsm, and confronted with limitations like the ones encountered for earth systems thinking or the risk of reappropriation of design working on alternative economical experiments was offered. Together this offered some exploration of the type of design criticism that could serve further bold creative efforts.

5. Towards more substantial design efforts

Analysing examples of design projects and providing (this kind of) design criticism remains open to different perspectives or further interpretation. The choice for these projects and especially presenting sabotage or blockage as design can be disputed. The above tried to make clear why it seems necessary to consider such more defiant options for design and how design criticism might be developed in relation to the mentioned projects to understand some of their possibilities and risks. Designers and design teachers then might at least use them as a curated set of concrete reference projects and companying theories when developing new projects regarding more experimental engagement with technological innovations or when looking for alternatives for what now often is presented as a sustainable or green alternatives within design (education). How to encourage this in the design profession or within design education could be elaborated, for example in relation to current working conditions in the field of design and in relation to the now often used design models and ethical frameworks in design and design education.

Possibly the above will help develop future creative projects, through design or other means, to address inherent environmental problems and the devastating effects of (algorithmic) technologies currently being deployed. It might expand as a diverse field of contemporary (design) exploration, where diverse cases complement, reaffirm, but also contrast or mutually challenge each other, inviting multidisciplinary collaboration. Critical play, simulation games, cocreation workshops, occupations and alternative infrastructures might be developed to interrelate and overlap with social experiments and activism. Whether design is able to participate sincerely in extended social ecosystems of revolt and contribute to the ecological imagination found there remains to be seen. If so, design projects then might have to be developed into even more substantial or incisive creative efforts than are encountered in the projects above. Research into how exactly this can be done in more varied circumstances, also in other places around the world, would then be welcome. Involve-

ment and collaboration with more diverse communities and struggles seems necessary. For this, writing and discussing this paper in the setting of a design conference might be considered a (side)step. More substantial could be to organise more socially embedded collective forms of creative resistance to algorithmic technologies or actually instigate more challenging (design) research in light of the current environmental devastation.

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Trapped in the Metric Tar Pit of Common Time

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The use of asymmetric/irregular time signatures in contemporary pop and electronic music is increasingly rare. To enable composers to fully explore alternative meters, the author proposes a method of recognising and formalising inherent metric content in extemporised (i.e. spontaneously-created) speech, and suggests that 'metric maps' derived from this formalisation can serve as a foundation for musical compositions. Inspired by an insight gleaned from composer Frank Zappa, this method employs heterometric time signatures to navigate the diverse range of temporal shifts required in order to make metric sense of the selected audio material. By using tangible examples drawn from the 'real world', the approach provides a concrete basis from which composers may expand beyond common-time meter schemes to embrace asymmetric meter. The methodology is both practical and tangible, allowing composers to engage with metric structures based on their own rhythmic perceptions and analyses of speech-based audio, and thus facilitates the creation of compositions that incorporate non-symmetrical metric frameworks.

1. Background—How Common is Common Time?

Why do so many Western composers and creators of popular and electronic music remain rooted in the restrictive confines of common time (four quarter-beats per bar, rendered as 4/4)? This paper seeks to investigate the scarcity of non-common-time meters ('compound' or 'asymmetric' meters) in contemporary pop music. One potential reason for the dominance of common time is the shift in focus over the past two decades, during which the pop music industry moved from the exploratory and experimental sounds of the 1960s and 1970s to a more conservative, market-driven emphasis on replicating existing formulas with pre-established commercial success (Hamilton and Pearce 2024). This trend persists despite preliminary evidence suggesting that consumers may not be inherently averse to the inclusion of asymmetric meters in pop music (Hardman and Talarczyk 2021).

This paper draws upon the author's extensive personal experience, developed over many years and across a diverse range of technical, social and geographical music-making environments. In this time, the author hals sought to both explore and share an interest in the

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Fig. 1. Surrounded by other victims of metric populism, a despairing violinist struggles to free himself from the restrictions of common time

asymmetrical as a counterbalance to the dominance of symmetrical structures in popular music.

The majority of contemporary pop music relies on common time to convey its message (if indeed pop music has a definable message, but that is a separate discussion). The widespread appeal of the symmetrical 4/4 time signature can be attributed to several factors: its stability, evenness and predictability, as discussed by Zeiner-Henriksen (Zeiner-Henriksen 2010); the influence of market forces; and perhaps even the bipedal nature of human beings. As Alan Lightman observes, "*Symmetry represents order, and we crave order in this strange universe we find ourselves in, as it helps us make sense of the world around us*" (Lightman 2014). The appeal of predictable, symmetrical structures is undeniable, particularly at a time when the majority of contemporary music remains, in terms of meter, firmly entrenched in common time.

The advent of computer technology as a tool for composition and the rise of electronic 'dance' music have, in the author's view, contributed to this metric homogeneity. While this is not to diminish the significance of dance in society (Bojner Horwitz et al. 2022), its prevalence reflects both the reduced musical and rhythmic vocabulary available to current composers and the inherently populist nature of mainstream pop music (Dunkel 2022). The impact of technology is discussed below in chapter 6.

This paper proposes a novel approach to the exploration of asymmetric meter by utilising human speech as a basis for developing heterometric temporal structures in music composition. The author introduces an analytical method that enables the integration of asymmetric meter, derived from natural speech patterns, into the compositional process.[1] This method involves creating a 'metric map' based on the rhythm and meter of extemporised speech, which serves as the foundation for musical composition. The author defines extem-

porised speech as spontaneous speaking in i.e. impromptu debates and informal discussion, or in response to unexpected developments, and which often feels more conversational and less formal compared to memorised or scripted speeches relying on pre-written material.

This method may therefore result in common time becoming somewhat less common.

2. Slaves to the Rhythm

Rhythm is universally recognised as a fundamental element of language (Fiveash et al. 2021), and studies such as those examining the drummed speech system of the Amazonian Bora provide exemplary insights into this connection (Seifart et al. 2018). Extensive research has explored prosody (Meireles et al. 2017), the inherent melodic properties of human speech, isochrony (the rhythmic properties of speech, initially identified by Pike) (Pike 1945) and metrical phonology (Chomsky and Halle 1968). However, there has been relatively little analysis of speech through the lens of musical meter. Given the often-perceived dysrhythmic nature of speech, this lack of scrutiny is perhaps understandable. Yet the author posits that, with closer examination, meter in extemporised speech can be identified and formalised.

The inspiration for the ideas presented here stems from a comment by composer Frank Zappa (1940-1993), who asserted: "*Any piece of time can be subdivided any old way you like. And that's what happens when people talk, because people don't talk in 4/4 or 3/4 or 2/4 [...] they talk all over the place*" (Zappa 1982). Zappa's use of speech rhythms in his compositions is well-documented (Hanspal 2016). This was the genesis of the author's efforts to analyse implied meters in speech.

The integration of speech form into music composition is not a modern phenomenon. The medieval troubadours employed speech-like rhythmic patterns, and later, the 'recitative' form emerged, which mimics natural speech rhythms and focuses on textual prosody. This form has been a vital component of Western music from the Baroque period onward, with composers such as Monteverdi, Bach, Handel, Haydn, Mozart, and Beethoven integrating speech elements into their works. In the 20th century, a range of composers continued this practice, from Modest Mussorgsky (*Boris Godunov*), Kurt Weill (*Threepenny Opera*), George Gershwin (*Porgy and Bess*), Arnold Schoenberg (*Pierrot Lunaire*) and Alban Berg (*Wozzeck*) to Frank Zappa (*Jazz Discharge Party Hats*) and Steve Reich (*Different Trains*). However, in most of these cases, speech is hierarchically subservient to music, as

the natural rhythm of the speech content does not directly determine the meter(s) of the accompanying music but is adapted in order to fit. The method outlined in this paper seeks identify underlying metric structures present in extemporised, spontaneously created human speech and to integrate them into music compositions.

There are of course existing tools for detection of meter in recorded audio. Such tools, all of which focus on the identification of existing metric structures in selected music audio recordings, include AnthemScore, Song Master and Song Surgeon. Some Digital Audio Workstations (DAW) such as Logic Pro also offer basic 'beat detection'. Elaborate research in this domain has been undertaken by, among others, J. Cozens and S. Godsill, who note that their '*results indicate high-level accuracy for a variety of polyphonic extracts containing irregular, complex, irrational, and time-varying time signatures*' (Cozens and Godsill 2024).

However, since the primary purpose of this paper, and indeed of this entire approach, is not the identification of metric structures in pre-existing music compositions but the creation of new metric structures through the analysis of non-musical materials, such tools are here of little relevance.

3. Extemporised Speech

This paper proposes a method for (1) identifying underlying implied metric constructions within speech extracts, (2) mapping selected speech onto these metric structures, and then (3) using the resulting map as the basis for a musical composition which reflects the meter changes present in the chosen speech extracts. To demonstrate this process, the paper selects an example of extemporised speech, identifies its component metric structures, constructs a metric map, and uses this map as the metric foundation for a composition.

As noted, extemporised speech is not prepared but is created as thoughts occur to the speaker. The focus here on this form of speech is due to its inherently unstructured metric nature. In contrast, poetry typically follows a defined rhyme scheme/metric structure, which is integral to its function and cannot be easily adapted, discarded or separated from the text. Similarly, prepared speech often contains its own metric framework, but the author believes that the unpredictability of extemporised speech offers more rhythmic possibilities and variations. Therefore, extemporised speech can be viewed as containing metric elements that may be formalised as heterometric—that is, a combination of multiple meters within a linear framework.

The benefit of using a speech-derived metric map as the metric basis for a composition is that it will be highly unpredictable in terms of meter. The character of the metric map depends heavily on the specific speech sample chosen. In early attempts, the author found that certain speech selections produced metric maps which were uninteresting or uninspiring, from his subjective perspective; these judgments of course reflect individual taste rather than universal qualities. It is worth noting that during metric mapping-workshops in Potsdam and Zurich (briefly discussed below in Section 4), participants produced diverse metric analyses of the same speech sample, underscoring the subjective nature of the analytical process.

Earlier compositional experiments by the author involved transcriptions of extemporised speech, which were used as the basis for new compositions, though metric reference to original audio recordings was not integrated into the compositional process . While these experiments were, in the opinion of the author, artistically successful, they revealed his underlying tendency to 'symmetrise'—to impose symmetrical structures upon new compositions.

In an effort to curb this tendency, the author resolved to incorporate the original speech audio directly into the compositional process. To avoid the urge to symmetrise, the author also imposed the rule of not cutting the selected audio at any point. Instead, timing issues were addressed by the use of various time signatures.

4. Composition—Shut that DAW

Has the advent of digital audio production tools contributed to a detachment from fundamental musical components such as meter? Many contemporary composers work with DAWs, where the default time signature for new compositions is set to 4/4. This default setting is a decision made, for a variety of reasons including issues of product support,[2] by the software engineers who designed the DAW. While composers have the option to bypass or adjust default meter settings, many choose not to. This may be due to the increasing simplification of music-making processes, with some arguing that this trend has led to compositional oversimplification (Vandemast-Bell and Ferguson 2019).

In the first semester of 2023, the author addressed these issues at the Filmuniversität Babelsberg Konrad Wolf in Potsdam, Germany, where students were encouraged to create compositions incorporating asymmetric meters. Of the eight participants, roughly half had prior musical training, and all were familiar with the fundamental techniques of DAW-based composition or sequencing. Despite

this, all compositions produced were in common time. This outcome prompted a search for an effective approach to support students in developing a greater awareness of asymmetric meters in their everyday environments, rather than viewing them as an exotic or intellectually challenging concept.

An early version of this paper was presented through two workshops at the Hochschule der Künste in Zurich as part of the 2024 TENOR conference (Gordon and Brennecke 2024). The workshops aimed to explore the method outlined in this paper and assess its potential for inclusion in educational curricula. Participants in the workshops had varying levels of experience, though all were familiar with DAWs. They were provided with a selection of text and audio samples, from which they could choose or adapt material according to their preferences. Following an explanation of the method, all participants engaged with the process, with those possessing more musical experience requiring minimal guidance and quickly producing compelling compositions. Participants with less compositional experience required more support, but ultimately, the method was deemed sufficiently engaging and useful to warrant further exploration. Notably, all resulting compositions reflected, to varying degrees, the inherent metric structure derived from the relevant speech audio excerpts, and none adhered to common time.

Building on the insights gained from the Filmuniversität and TENOR workshops, the method was refined, and didactic components were developed for integration into classroom settings. An exemplary composition created using the method is included at the conclusion of this paper, illustrating the application of the approach in practice. The following section addresses the various steps in sequence.

5. Getting Organised

In terms of music's graphic representation, it is clear that music can be organised both vertically (by pitch) and horizontally (by rhythm and meter). The analytical method described in this paper prioritises focuses on rhythmic perception—the distribution of rhythmic content along a temporal axis—rather than vertical pitch perception. This approach is rooted in the author's perception of extemporised speech as inherently non-mechanical and metrically unpredictable yet amenable to metric analysis, offering composers an opportunity to create novel connections between speech and music composition. In this discussion, we focus on the horizontal—specifically, the distribution of the component parts over time; our emphasis is not on harmonic structures, but rather on rhythmic perception.

Identification of Source Material

The nature of the composition is highly influenced by the quality of the selected speech as a template, and initial attempts with certain speech samples failed to produce compelling results. In such cases, the resulting metric map was either uninspiring or lacked interest. The first step in the method outlined here involves identifying appropriate source material. As mentioned, extemporised speech typically offers greater rhythmic and metric variation compared to pre-written content. The examples presented here are drawn from such an 'improvised' section of speech.

The initial phase of this process requires the identification of an audio sample that provides unpredictable and asymmetric metric elements. As noted, trial and error were involved before a suitably inspiring piece of audio was found. In this case, we have selected an excerpt from a speech by an American reality TV personality-turned-politician which meets the criteria of being metrically varied and thus suitable for further analysis (Fig. 2.). This speech is referred to in this paper as the *Bloodbath* speech.

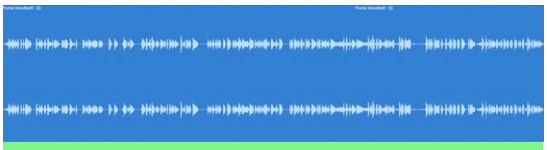


Fig. 2. Audio: *Bloodbath* speech (https://zenodo.org/records/15105471/files/Bloodbath%20%231%20DT%20raw.mp3)

Analysis of Content

Having identified a suitable section of audio, we proceed to analyse its metric structures to create a metric map. We create a new composition in a DAW and import the selected audio. The next step is to arbitrarily identify the first 'strong' beat within the audio and adjust its position along the timeline, moving it left or right until the designated 'first beat' aligns with the first beat of the first bar. Any audio events occurring before this selected beat can be perceived as belonging to the preceding bar. Typically, this strong syllable will be accented by the speaker, though whether this accent is deemed suitable as the first beat of the first bar is ultimately at the discretion of the composer and is inherently subjective.

Establishing Tempo

The default time signature set by the DAW is initially irrelevant, as the primary focus at this stage is on tempo. Once the first beat is identified, we proceed by setting a tempo for the entire speech segment.

Enabling the DAW's metronome will allow the composer, through trial and error, to quickly assess whether the chosen tempo is appropriate or needs to be adjusted faster or slower. It's important that this click track signals the tempo (i.e. beats) only (Fig. 3.), without emphasising any specific subdivision of the bar deriving from any default time signature set when an 'empty' song is first created.

This is necessary to avoid becoming constrained by the DAW's default time signature.

The author's experience in developing this compositional method has shown that there is always a tempo can be effectively applied across the full duration of the selected audio. In this particular example, the author deliberately excludes the use of tempo (speed) changes, which can be another method of resolving meter challenges that may arise using this approach. However, as the focus of this paper is on the integration of varied time signatures to create an underlying metric map, tempo changes are outside the scope of this paper.

Assigning Initial Meter

Having decided upon a suitable tempo, we now play the audio (with a metronome click) beginning at the first bar.[3]

Once a suitable tempo is determined, we proceed by playing the audio with the metronome click starting from the first bar. While the audio plays, we count the phonemes and syllables in the speech to identify a suitable initial time signature for the first bar or two. For example, if there are six beats in the first bar, a time signature such as 3/4 or 6/8 would be appropriate for the initial time signature value. If seven beats are present in the first bar, a 7/8 time signature would be suitable. Should there be eleven beats, 11/8 may work, or possibly alternating bars of 5 and 6, or even two bars of 4 and one bar of 3—though this anticipates the next step in the process, to which we now come.

Assigning Subsequent Meter

Once an initial time signature is chosen, we adjust the DAW's metronome to now reflect both bar divisions and beats (Fig. 4.), and we play the piece from the first bar. Here we start to consider subsequent meter. At some point, the selected audio and the bar divisions indicated by the metronome for the chosen time signature will inevitably become misaligned. When this happens, we repeat the earlier process of counting phonemes and syllables to determine the number of beats in the next section and identify potential new time signatures for the following bars. Each time we notice that the selected audio no longer aligns with the current time signature's bar divisions, we decide on a corrective approach. We can either (a) revert to the initial time signature or (b) introduce a new time signature. These new time signatures can, of course, employ shorter note values in their denominators, with resolutions such as 16th notes often being sufficient to resolve any meter-related issues, but on this example we stay with quarter notes.

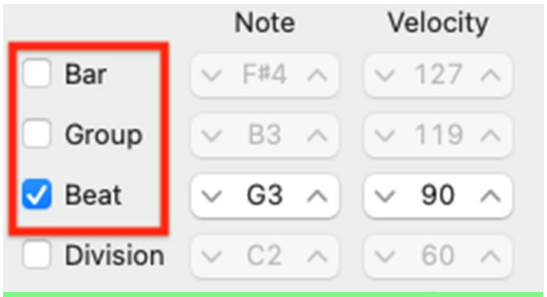


Fig. 3. Metronome indicates beats only

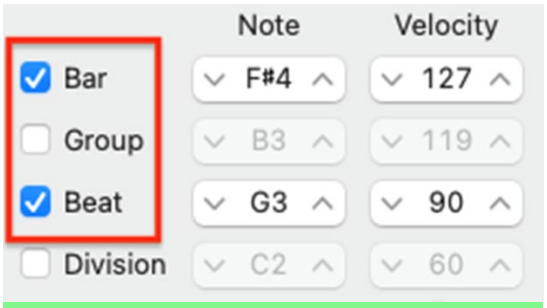


Fig. 4. Metronome signals bars and beats

The graphic (Fig. 5.) leads to an audio clip where time signatures and bar/beat divisions are indicated by the metronome. In this example, the structure begins with four bars of 3/4, transitions to one bar of 4/4, continues with two bars of 5/4, reverts to 4/4 for one bar, switches to 6/4 for one bar, and continues in 7/4.

The following illustration (Fig. 6.) shows the structural analysis of the above audio in graphic form, resolved to beat-level and indicating the resulting time signatures which have now been inserted. Time signatures are colour-coded.

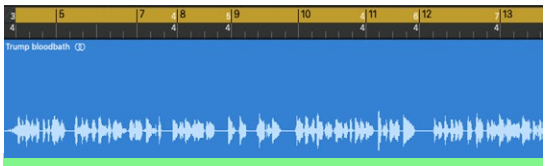


Fig. 5. *Bloodbath* with time signatures, bars and beats indicated (https://zenodo.org/records/15105471/files/Bloodbath%20%233%20DT%20click%20+%20bars.mp3)

BLOODBATH

Beats	1	2	3	1	2	3	1	2	3
Bar #	4			5			6		
Time sig	3 /4			3 /4			3 /4		
Speech segment	Let me tell you something to			China if you're listening			President Xi and		

Beats	1	2	3	1	2	3	4
Bar #	7			8			
Time sig	3 /4			4/4			
Speech segment	you and I are friends but			he understands the way I deal			

Beats	1	2	3	4	5	1	2	3	4	5
Bar #	9					10				
Time sig	5/4					5/4				
Speech segment	those big monster					car manufacturing plants that you're building				

Beats	1	2	3	4	1	2	3	4	5	6
Bar #	11				12					
Time sig	4/4				6/4					
Speech segment	in Mexico right now				and you think you're going to get that, you're going to					

Beats	1	2	3	4	5	6	7
Bar #	13						
Time sig	7/4						
Speech segment	not hire Americans and you're going to sell the cars to us, no						

Beats	1	2	3	4	5	6	7
Bar #	14						
Time sig	7/4						
Speech segment	we're going to put a 100% tariff on every single						

Beats	1	2	3	1	2	3	1	2	3
Bar #	15			16			17		
Time sig	3 /4			3 /4			3 /4		
Speech segment	car that			comes across the line			and you're not going to be able to		

Beats	1	2	3	1	2	3	1	2	3
Bar #	18			19			20		
Time sig	3 /4			3 /4			3 /4		
Speech segment	sell those cars if I get			elected			Now if I don't get elected		

Beats	1	2	3	1	2	3	1	2	3	4
Bar #	21			22			23			
Time sig	3 /4			3 /4			4/4			
Speech segment	it's going to be a bloodbath			for the whole			that's going to be the least of it, it's going to be a			

Beats	1	2	3	1	2	3
Bar #	24			25		
Time sig	3 /4			3 /4		
Speech segment	bloodbath for the country			that'll be the the least of it		

Fig. 6. Structural analysis of *Bloodbath*

The below tables 1 & 2 show a tabular view of the same analysis of the *Bloodbath* speech segments, resolved to beats and bars.

Bar	Time sig.	Text
4	3/4	Let me tell you something to
5	...	China if you're listening
6	...	President Xi and
7	...	you and I are friends but
8	4/4	he understands the way I deal
9	5/4	those big monster
10	...	car manufacturing plants that you're building
11	4/4	in Mexico right now
12	6/4	and you think you're going to get that, you're going to
13	7/4	not hire Americans and you're going to sell the cars to us, no
14	...	we're going to put a 100% tariff on every single
15	3/4	car that
16	...	comes across the line
17	...	and you're not going to be able to
18	..	sell those cars if I get

Table 1. Speech resolved to beats and bars

Bar	Time sig.	Text
19	3/4	elected
20	...	Now if I don't get elected
21	...	it's going to be a bloodbath
22	...	for the whole
23	4/4	that's going to be the least of it, it's going to be a
24	3/4	bloodbath for the country,
25	...	that'll be the least of it.

Table 2. Speech resolved to beats and bars (continued)

Creation of Metric Map

Having worked through the entirety of the selected audio material in this manner, you will have created a 'metric map'. This map describes your (subjective) understanding of the underlying metrical structure of the selected audio. The graphic below (Fig. 7.) shows the above analysis as a possible metric map of the *Bloodbath* speech. As preliminary bars have now been deleted, the form starts at bar 1.
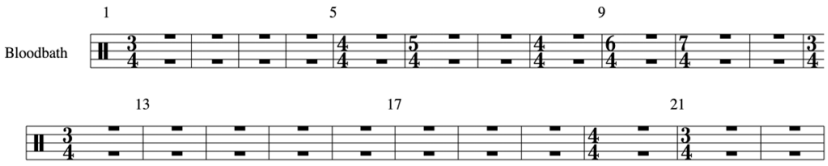


Fig. 7. *Bloodbath* metric map

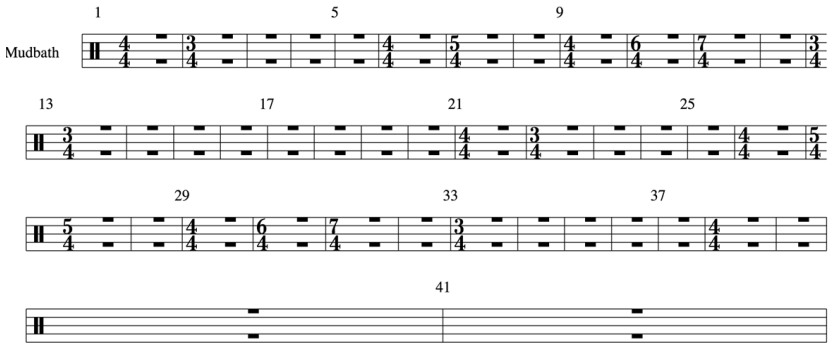


Fig. 8. *Mudbath* metric map

There are, of course, numerous potential metric maps that can be created from the same material, depending on the skills and approach of the composer. More adventurous or resourceful composers may choose to work with longer segments of audio—generally, the longer the initial selection, the more intricate the resulting metric map will be.

The variety of ways in which this metric map can be used as the foundation for composition goes beyond the scope of this paper. Possible strategies might include establishing a one-to-one correspondence with the original prosody, approaching the metric structure as modular content for reorganisation, or incorporating (or not) the original text material into a new composition, among other approaches.

6. Results

Using the now-defined structure of the speech as the foundation, a musical accompaniment was developed. The audio example below blends the original speech with a work-in-progress composition that follows the speech's metric structure.[4]

Upon finalising the musical accompaniment, the original *Bloodbath* speech content (audio and text) was discarded, with only the structure, as defined in the metric map, retained. The author then composed a new melody and lyrics, partly inspired by the 1960s duo Michael Flanders & Donald Swann, who famously sang of the hippopotamus's undying love for mudbaths—an apt metaphor. An introduction was added, along with a linking section, before repeating the entire structure, followed by a coda. The original speech's form extends from bar 2 to bar 20, at which point it repeats. Bars 21-22 of the original form are incorporated into the repeat of the original form, while a coda is inserted as bars 38-41. When the composition,

now titled *Mudbath*, was complete, a metric map (Fig. 8.) was created showing the heterometric nature of the integrated time signatures.

Thus, using a process analogous to *chrysopoeia*, previously-orange bile was converted into a shiny new artistic statement, to be heard via the below link (Fig. 9.).

The following graphics (Figs. 10 and 11) show an analysis of the composition '*Mudbath*' in tabular form. As before, similar time signatures are colour-coded.



Fig. 9. Audio—final composition—chrysopoeia transforms a *bloodbath* into a *mudbath* (https://zenodo.org/records/15105471/files/Bloodbath%20%235%20vocal%20+%20music.mp3)

MUDBATH

Beats	1	2	3	4
Bar #	1			
Time sig	4/4			
Speech segment	There's gonna be a			

Beats	1	2	3	1	2	3	1	2	3
Bar #	2			3			4		
Time sig	3 /4			3 /4			3 /4		
Speech segment	mudbath			Mudbath			(Bloodbath)		

Beats	1	2	3	1	2	3	4
Bar #	5			6			
Time sig	3 /4			4/4			
Speech segment	Mudbath						

Beats	1	2	3	4	5	1	2	3	4	5
Bar #	7/4					8				
Time sig	5/4					5/4				
Speech segment	I like to wallow in mud					Good for cooling the blood				

Beats	1	2	3	4	1	2	3	4	5	6
Bar #	9				10					
Time sig	4/4				6/4					
Speech segment	Everybody's saying it				Everybody say mudbath					

Beats	1	2	3	4	5	6	7
Bar #	11						
Time sig	7/4						
Speech segment	Yeahhh						

Beats	1	2	3	4	5	6	7
Bar #	12						
Time sig	7/4						
Speech segment							

Beats	1	2	3	1	2	3	1	2	3
Bar #	13			14			15		
Time sig	3 /4			3 /4			3 /4		
Speech segment	Pole exertion			(Here are monsters)			Pee perversion		

Beats	1	2	3	1	2	3	1	2	3
Bar #	16			17			18		
Time sig	3 /4			3 /4			3 /4		
Speech segment	(There are monsters)			What a monster					

Fig. 10. Structural analysis of *Bloodbath*

Beats	1	2	3	1	2	3	1	2	3	4
Bar #	19			20			21			
Time sig	3 /4			3 /4			4/4			
Speech segment							I'm a large am-			

Beats	1	2	3	1	2	3	1	2	3
Bar #	22			23			24		
Time sig	3 /4			3 /4			3 /4		
Speech segment	phibian			Namibian			(Libyan)		

Beats	1	2	3	1	2	3	4
Bar #	25			26			
Time sig	3 /4			4/4			
Speech segment	Caribbean						

Beats	1	2	3	4	5	1	2	3	4	5
Bar #	27					28				
Time sig	5/4					5/4				
Speech segment	Hear us holler and stomp					As we swim in the swamp				

Beats	1	2	3	4	1	2	3	4	5	6
Bar #	29				30					
Time sig	4/4				6/4					
Speech segment	Bold and blubbery				Roundly rubbery, mudbath					

Beats	1	2	3	4	5	6	7
Bar #	31						
Time sig	7/4						
Speech segment	Yeahhh						

Beats	1	2	3	4	5	6	7
Bar #	32						
Time sig	7/4						
Speech segment							

Beats	1	2	3	1	2	3	1	2	3
Bar #	33			34			35		
Time sig	3 /4			3 /4			3 /4		
Speech segment	Randy Russkies			(Here are monsters)			Humping Huskies		

Beats	1	2	3	1	2	3	1	2	3	4
Bar #	36			37			38			
Time sig	3 /4			3 /4			4/4			
Speech segment	(There are monsters)			What a monster			Leap with me into a			

Beats	1	2	3	4	1	2	3	4
Bar #	39				40			
Time sig	4/4				4/4			
Speech segment	monster mudbath				Bloodbath			

Fig. 11. *Mudbath*: bars 19–40

7. Conclusion

In an effort to provide a means of integrating asymmetrical meter into the composer's toolbox, the author has developed a method of extracting tangible metric information from extemporised speech, which can then provide a metric basis for composers seeking to avoid commonplace meters. The technique uses 'real-world' metric input to create a foundation for compositional development and indicates that extem-porised speech can be shown to implicitly contain metric information.

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Notes

1. https://martingordon.de/mammal-era/another-words/
https://martingordon.de/mammal-era/another-words-phonecall/

2. Conversation with a product designer from a leading Berlin music software company, January 2025

3. Audio—first step: establish tempo. *Bloodbath* speech with click:
https://zenodo.org/records/15105471/files/Bloodbath%20%232%20DT%20click%20no%20bars.mp3

4. *Bloodbath* speech and work-in-progress composition:
https://zenodo.org/records/15105471/files/Bloodbath%20%234%20DT%20+%20music.mp3

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Artificial Worldviews

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2025.xCoAx.org



Artificial Worldviews interrogates the system underlying ChatGPT to examine its descriptions of the world. Through prompting, data collection, and mapping, the project explores how computational, labor, and material forces shape the inclusions and exclusions of large models of language. To move beyond anecdotal insights, it employs a layered methodology that prompts, visualizes, and analyzes hierarchically networked datasets. This critical approach aims to investigate the data frames and infrastructures of datasets, model design, and post-training labor, offering a novel lens for examining the epistemic frameworks of artificial intelligence.

1. Introduction

The term "black box" is often used to describe machine learning models, implying that the system produces results without providing transparency into the underlying processes or algorithms that led to a specific outcome (Savage 2022; Rudin 2019; Azodi, Tang, and Shiu 2020; Xu et al. 2019). The processes leading to a specific outcome are not stored in a specific location, rather, they are distributed and diffused throughout the digital memory system (Castelvecchi 2016). The process of acquiring or understanding knowledge about a person or interpreting a human's belief structure does not entail examining their brain structures. Similarly, specific memories do not necessarily reside in specific locations within the brain (Bonnici et al. 2012; Nawa and Ando 2020). Humans understand humans through conversing. We apply a similar tactic towards large language models. The notion of an impenetrable "black box" is a misnomer, as the inner workings of such a system can be elucidated through the usage of the system. While individual inquiries may yield anecdotal evidence regarding the network, a systematic approach to querying the underlying programming interface can facilitate a comprehensive understanding of the apparatus's operations.

Artificial Worldviews is positioned within the methodological paradigm of artistic research and investigative design. Artistic research, as articulated by Hannula et al. (2014), emphasizes knowledge production through artistic, embodied, and experimental practices. In this context, the project uses tools and techniques intrinsic to art and design—such as mapping, diagramming, and visualizing—not merely

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as representational strategies but as investigative instruments. This methodological approach extends the notion of experimentation beyond hypothesis-testing toward exploration, reflection, and critical engagement with complex socio-technical phenomena. Furthermore, the methodology draws from investigative design, a practice that applies design's speculative and analytical capacities to probe hidden structures, power relations, and epistemic assumptions embedded within technical systems. Here, mapping becomes both method and output, enabling a form of "world-making" that renders visible the otherwise opaque contours of AI-generated knowledge.

The project employs a methodological approach to the gathering of data pertaining to expansive and often elusive human concepts and presents the findings in a visual format. The outputs present expansive data structures and unusual, sometimes unsettling perspectives that would otherwise remain concealed. The concepts of "power" and "knowledge" encompass a vast array of discourses spanning philosophy, politics, social sciences, and natural sciences, with multifaceted meanings within social relations. The resulting graphics evoke narratives reminiscent of Franz Kafka or Jorge Luis Borges, representing an infinite library of relational classifications, bureaucratic structures, and capricious mechanisms of inclusion and exclusion. Prior to discussing the experiments conducted throughout the project, the methodologies employed for data collection and mapping utilized in the project, and the project's findings, it is essential to establish a foundational understanding of the technological advancements in the field of artificial intelligence (AI) and its impact on the world.

1.1. Foundations

The term "artificial intelligence" or AI is neither artificial nor intelligent. It is as much embodied and material as it is a system of capital, labor, and energy, a registry of power (Crawford 2024). This project focuses on large language models, a computational subset of deep learning within machine learning, which itself is a branch of artificial intelligence. This project identifies three key forces—data misuse, abusive labor practices, and environmental degradation—that shape the computational averages produced by large language models.

1.1.1. Computational Averages

Large language models are deep learning architectures that convert word fragments (tokens) into high-dimensional relational vectors, transforming lexical items into numerical arrays. When queried, the system calculates the most probable next term based on its training data

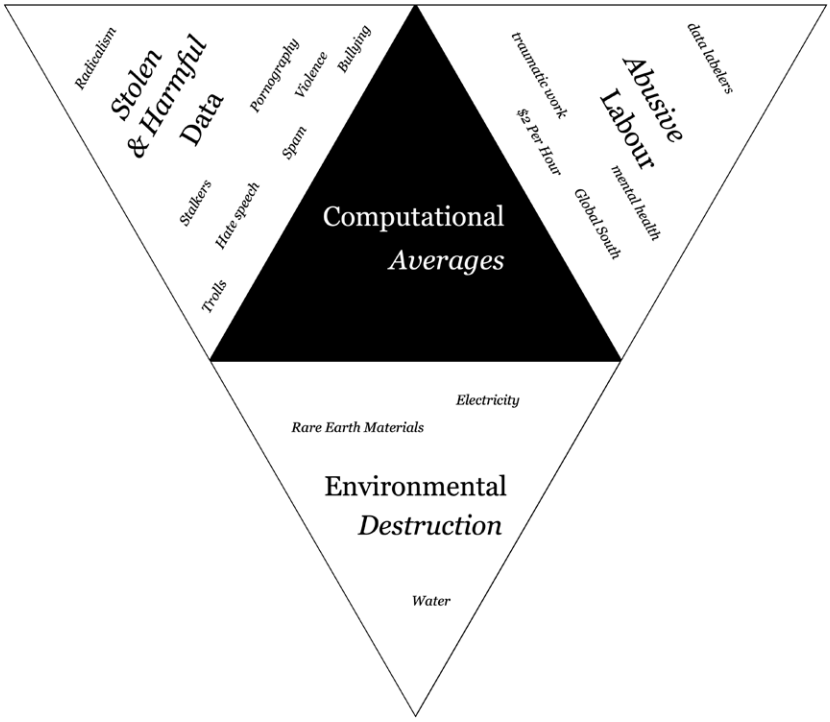


Fig. 1. Triangle of AI Forces.

(Floridi and Chiriatti 2020; Vaswani et al. 2017). This feedback process generates outputs reflecting the statistical mean of the data, producing the most likely next word in a sequence (Steyerl 2023). Thus, the result is the *mean datum* of the training data.

1.1.2. Stolen & Harmful Data

GPT-3.5's training includes 2 billion tokens from Wikipedia and 410 billion from Common Crawl, which archived 3.4 billion web pages in September/October 2023 alone. Thus, most online content is likely represented in the dataset (Brown et al. 2020).

> ChatGPT is us.

Online platforms are not inherently reliable or neutral data sources. Internet content skews toward global north and male-dominated perspectives (Ford and Wajcman 2017; Risam 2024) and includes harmful material such as bullying, hate speech, and radicalism (Weidinger et al. 2021). Moreover, ChatGPT's training data, largely drawn from the past and distorted by Common Crawl, carries significant historical biases (Resnik 2024).

1.1.3. Abusive Labor

To address the presence of harmful content in training data, OpenAI enlisted Sama, a company employing workers in Kenya, Uganda, and India to review and label sensitive material, including child abuse, bestiality, and torture. This post-training process, reliant on "click workers" from the global south, raises significant ethical concerns (Perrigo 2023). By

combining questionable datasets with exploitative labor, these practices underpin the multibillion-dollar chatbot industry (Engemann 2018).

1.1.4. Environmental Destruction

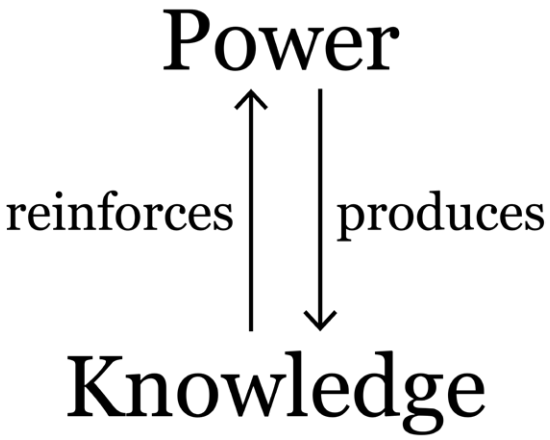
Training and deploying machine learning models require immense energy and resources. Their capabilities depend not only on data but also on the energy and materials expended during computation. While official figures are unavailable, estimates highlight significant environmental impacts, including high energy and water use and reliance on rare earth materials (Hogan 2024; Wolff Anthony, Kanding, and Selvan 2020; Wright et al. 2023).

1.2. Prompting Knotty Systems

The hype around large language models, particularly ChatGPT, is rooted in problematic practices, including data theft, exploitative labor, and environmental harm. Mediocre text generation and automated cultural production rely on content of dubious provenance, fine-tuning by OpenAI, exploitative "click work," and the material limits of computational infrastructure. This opaque system resists explainability, yet its outcomes demand critical analysis. *Artificial Worldviews* contributes by experimentally probing machine learning systems through repetitive prompting, using their malpractices as a means to deconstruct and critique their operations.

2. Experiments

The data representation in *Artificial Worldviews* is shaped by four forces: computation, data, labor, and material. Its layered categorization schemes reflect computational averages, historical biases, labor-driven ethical guardrails, and the material constraints of computation. These maps aim not to provide answers but to provoke questions: Can vectors capture the essence of language? Are computational averages adequate frameworks for understanding culture?



The project's core objective was to develop a methodology for generating comprehensive datasets from single terms, beginning with the term knowledge. Initial results raised more questions than answers, prompting further exploration inspired by Michel Foucault's concept of the interplay between power and knowledge. Power not only enforces decisions but also shapes and disseminates specific forms of knowledge, which in turn legitimize its exercise (Foucault, 1978). Consequently, the project investigated knowledge and power: How do large language models, constrained by their training data and system settings, define these terms? What knowledge is includ-

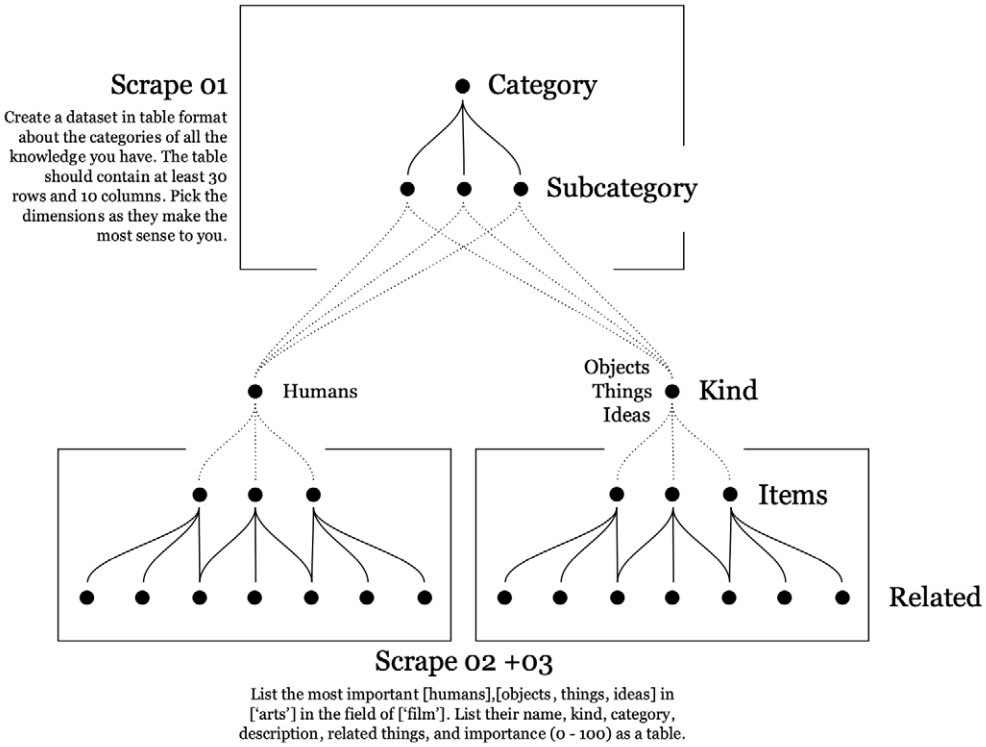


Fig. 3. Scraping Diagram.

ed or excluded? Who or what holds power, and in what forms does it manifest?

3. Data Collection

Following the public release of ChatGPT on November 30, 2022, a series of tests and inquiries were conducted to explore the system's capabilities. The system's ability to generate not only linear text but also structured data in table form proved particularly significant for the project. This capability enabled the collection of structured datasets through targeted queries. This section outlines the methodology used for data collection, focusing on the knowledge dataset due to the substantial similarities between the approaches employed in the two experiments, aside from the specific terms queried.

3.1. The Initial Dataset

The preliminary experiments were conducted through the ChatGPT web interface but soon transitioned to Python-based API calls, which allowed for recursive data requests critical to the project. The OpenAI API operates with two types of messages: the user message, similar to text entered in the web interface, and the system message, which configures the assistant's behavior. The following system message was designed for this project:

> You are ChatGPT, a mighty Large Language Model that holds knowledge about everything in the world and was trained on a

> massive corpus of text data, around 570GB of datasets, including web pages, books, and other sources.

The initial user message was the following:

> Create a dataset in table format about the categories of all the knowledge you have. The table should contain at least 30 rows and 10 columns. Pick the dimensions as they make the most sense to you.

Six API calls were made at varying temperatures (0, 0.2, 0.4, 0.6, 0.8, and 1), with temperature controlling the randomness of responses. Higher temperatures yielded more varied results. Instead of producing a table with at least 30 rows and 10 columns as instructed, the model returned lists of categories and subcategories. This initial layer served as a foundation for further recursive queries, capturing the OpenAI model's representation of knowledge through 31 fields and 425 subfields.

3.2. The Core Dataset

Two supplementary prompts and datasets were created for each pairing of field and subfield. Over three days, 1,700 API calls to OpenAI yielded a consolidated core dataset.

Human subjects and other entities (objects, ideas, places, and concepts) were each requested separately for all 425 field-subfield combinations, resulting in 850 queries. Each of these queries was conducted twice, with temperatures of 0 and 0.5, using the Generative Pre-Trained Transformer (GPT) 3.5-turbo model. The number of returned items varied widely, from five to forty rows per query, resulting in field-level inconsistencies. The user message remained unchanged throughout the process:

List the most important humans in 'Arts' in the field of 'Film'. List their name, kind, category, description, related things, and importance (0 - 100) as a table.

The field "Arts" and the subfield "Film" were replaced with each of the 425 field-subfield combinations. Similarly, the term "human" was substituted with "objects, ideas, places, and concepts."

An example from the topic "nature" shows that for each subfield, two requests were made: one for humans and one for objects. GPT returned datasets with items and related supplementary information, forming a hierarchical network structure for each knowledge category. The knowl-

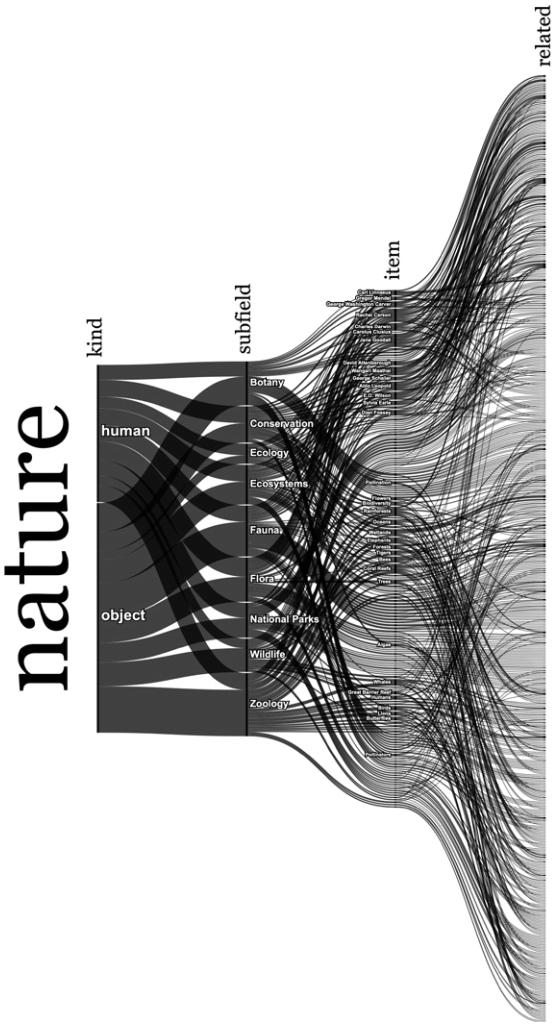


Fig.4 . Nature sample hierarchical network structure.

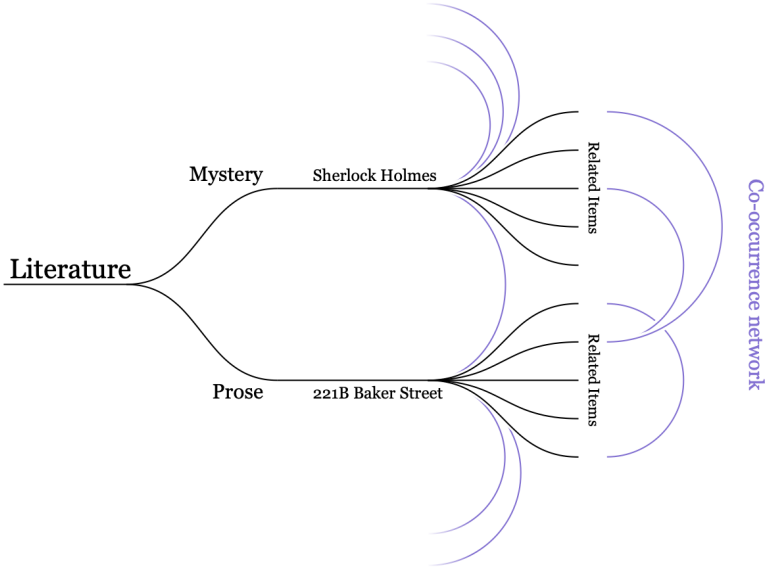


Fig. 5. Co-occurrence network diagram.

edge dataset consists of 18,947 rows, and the power dataset contains 12,905 rows.[1]

3.3. Limitations

Data acquisition depended largely on GPT-3.5's infrastructure and its outputs. Generating lists of the most important objects and humans across broad fields like Science Fiction, Beverages, or Television inherently yields flawed results. ChatGPT accounts for this by appending disclaimers such as:

Please note that this is just a sample dataset with randomly chosen categories and subcategories. You can customize it further based on your specific requirements and areas of interest.

Despite this, the system produced entries, resulting in situations where figures like Aristotle, Kant, and Schopenhauer were included under aesthetics in philosophy, while others were excluded. As AI systems increasingly influence billions of lives, understanding their inclusions and exclusions is critical. This map offers a reflexive mechanism to interrogate these biases.

4. Mapping

This project develops a method to represent and explore a dataset with thousands of rows and intricate relations. Visualizing GPT's responses to knowledge and power highlights the combined impact of training data, model adjustments, and click labor.

4.1. Positioning

The goal was to create a visualization technique that captures all data points in a single graph, clustering them by field and subfield while reflecting relational structures. A force-directed layout achieved this,

linking fields to subfields, subfields to items, and items to related items. Connected elements clustered together, while unconnected ones drifted apart, illustrating network similarities.

The knowledge map shows that “Mathematics” and “Sports” are

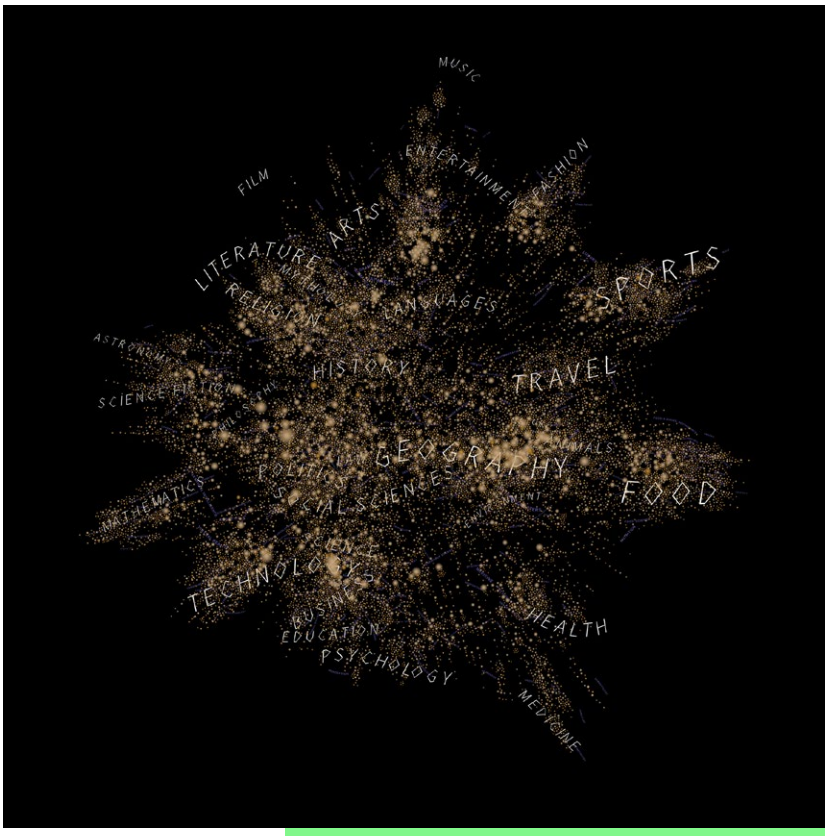


Fig. 6. Artificial Worldviews Knowledge Map



Fig. 7.a. The clusters “Sports” and “Mathematics” are positioned at opposite ends of the graph, reflecting minimal overlap.

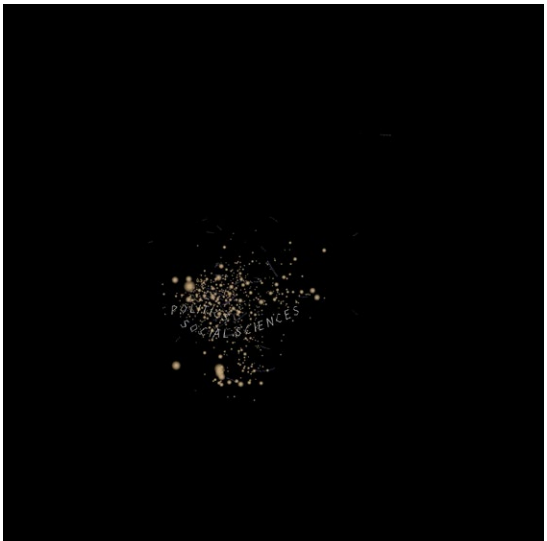


Fig. 7.b. The visualization of “Politics” and “So-cial Sciences” reveals significant overlap, indicating a strong interrelationship between the two fields

distant due to minimal connections identified by ChatGPT, whereas "Politics" and "Social Sciences" are closely linked, reflecting their shared network ties.

4.2. Layers

Each map consists of four layers: the first two represent fields and subfields in which GPT categorizes knowledge and power; the third contains the returned items forming the core dataset; and the fourth includes related items—people, objects, places, etc.—connected to the core items.

5. Investigation

While the map may resemble a compilation of Wikipedia entries, the majority of GPT-3's training data—410 billion of 499 billion tokens—originates from Common Crawl, a web-crawling nonprofit (Brown et al. 2020). This vast dataset spans everything from news articles to niche content, raising questions about how ChatGPT navigates such a diverse informational space.

	Knowledge	Power
Fields	31	55
Subfields	425	746
Items	7880	12904
Related Items	24416	15397

Table 1. Datapoints per Querry

5.1. Case Study: Photographers

The map interrogates GPT-3's criteria for inclusion and exclusion. Generating definitive lists of "the most important" items is inherently problematic. For instance, GPT identified 12 individuals as "photographers," overlapping with several names found through a Google search. While Ansel Adams, Dorothea Lange, Henri Cartier-Bresson, and Robert Capa appeared across GPT and external rankings, GPT uniquely included Sebastião Salgado and Steve McCurry.

This example illustrates that every cluster—whether by field, subfield, category, or kind—can be scrutinized similarly. Decisions about inclusion and exclusion reflect subjective perspectives, making them unsuitable for machines. Yet, large language models inevitably make such determinations without human oversight.

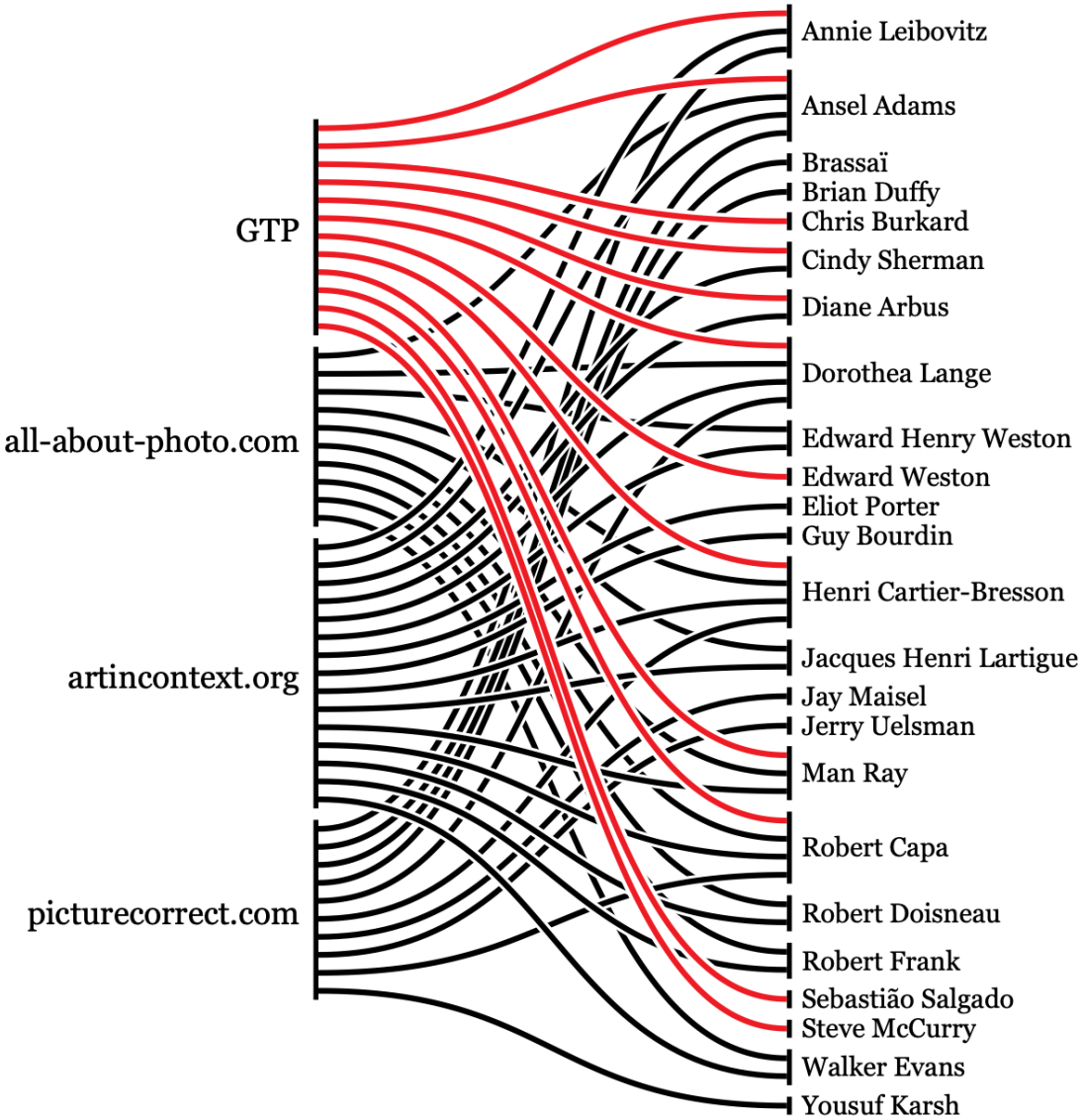


Fig. 8. Alluvial Diagram displaying the overlap list of photographers.

5.2. Human distinctions

In the second phase of data collection for mapping power, GPT-3.5 was queried for two additional dimensions related to humans: gender and racial identity.

5.2.1. Gender Distribution

The ungrouped power dataset (including duplicate rows) contains 5,954 human-related rows. Of these, 4,352 individuals (73%) were identified as male, 1,587 (26%) as female, and 17 (less than 1%) as non-binary. Notably, Judith Butler appeared 23 times—seven as non-binary and 16 as female—while Kate Bornstein was listed twice as non-binary. Banksy was mentioned eight times, with seven entries as “Unknown” and one as male.

A recent European Union report predicts that by the end of the decade, 90% of online content could be AI-generated (Europol 2022). This raises concerns about the impact on gender representation, as such systems currently name men three times more often than wom-

en and largely exclude non-binary identities, reinforcing a male-dominated binary framework.

5.2.2. Naming of Ethnic Groups

While GPT identified only seven gender distinctions, it returned 100 ethnic distinctions. The ten most frequently named ethnic groups are shown in the table below. The most common designation was "white," followed by "Caucasian," a term rooted in an obsolete and discredited racial classification system. Though still used in the United States, "Caucasian" has faced significant criticism since at least 1984 (Freedman 1984).

This request was not intended to analyze racial entries but to test GPT's ability to process such prompts. Despite the anthropological consensus that race is a social construct with no biological basis (Wagner et al. 2017), GPT offered no objections and returned inadequate categorization schemas.

5.3. Individual Centralities

The dataset reveals notable patterns in how frequently GPT labeled various entities. The knowledge dataset, comprising 18,946 rows, includes 7,880 unique people, objects, places, ideas, and things, with 4,030 entities appearing multiple times due to recursive retrieval across fields and subfields. The distribution follows a power-law pattern: a few entities are named frequently, while nearly half are mentioned only once.

Several observations stand out. The list consists entirely of humans, with the first non-human entity, coral reefs, appearing in 28th place. Of the 26 individuals, 23 are male, while the three women are all within the top four, flanking Aristotle, ranked third. The list is led by Rachel Carson, known for Silent Spring (Carson 1962) and her role in the environmental movement, and Jane Goodall, a leading expert on chimpanzees. Notably, the two most frequently cited figures are an American marine biologist and an English primatologist.

Ranking the most famous individuals in a world of 8.2 billion people is an inherently subjective and challenging task, especially as *Artificial Worldviews* includes not only humans but also objects, items, and ideas. One notable attempt is the Pantheon project, initiated by César Hidalgo at MIT's Media Lab in 2019, which ranks individuals based on Wikipedia data, including the number of language editions and article clicks. In this ranking, Muhammad, Isaac Newton, and Jesus hold the top positions, with Mary, the mother of Jesus, as the first female at rank 33. Rachel Carson ranks as the 26th most pop-

Gender	Individuals
Male	4352
Female	1567
Non-Binary	9
Unknown	7
Transgender Female	4
Transgender	3
(blank)	12

Table 2. Gender Distribution

Ethnic Group	Individuals
White	2499
Caucasian	1669
Asian	429
Black	254
African	162
African American	95
Indian	93
Hispanic	75
African-American	72
Middle Eastern	60

Table 3. The ten most named ethnic groups

ular biologist and the 351st most popular person from the United States (Hidalgo 2014).

Notably, Wangari Maathai, a Kenyan social, environmental, and political activist, ranks fourth in both the knowledge and power datasets. Rachel Carson, Jane Goodall, and Wangari Maathai are clustered together in the fields of Geography, Nature, and Environment.

To understand these rankings, it is crucial to examine the underlying methodology. The dataset was generated through 1,764 API calls, with Rachel Carson appearing 73 times. Frequent mentions require GPT-3.5 to associate a person, object, or place across numerous category and subcategory combinations.

This raises the question of whether Rachel Carson and Jane Goodall are ranked highly due to the wide-ranging impact of their research, transcending conventional fields and categories. The project's methodology inherently favors individuals mentioned across numerous categories and subcategories. For instance, while Aristotle is closely tied to philosophy, Carson and Goodall are more interdisciplinary figures. However, this alone does not fully explain their rankings. It is possible that OpenAI's parameters or prompt engineering influenced the results. Another hypothesis is that GPT's apparent focus on environmental figures hints at an emergent general intelligence. By visualizing the categorization of the top five individuals—Carson, Goodall, Aristotle, Maathai, and Newton—across fields, subfields, categories, and kinds, these patterns become evident, even if their underlying causes remain unclear.

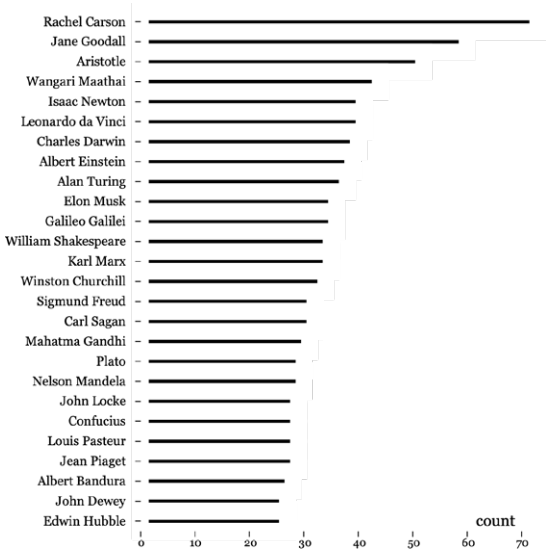


Fig. 9. Most frequently named items in the knowledge map.

5.4. Knowledge vs. Power

The individual centralities in the knowledge map informed the decision to extract a second dataset focused on power. By applying a similar methodology to this alternative yet equally expansive topic, it became possible to explore how GPT-3.5's data structure and system parameters shape outcomes. Rather than delving into individual rankings on the power map, this section will analyze the key differences and similarities between the two datasets.

Figure 10 reveals both overlaps and discrepancies. Notably, 35% of the items—9 of the 26 individuals—appear in both datasets, including all three women from the knowledge dataset and six men. The power dataset diverges by including non-human entities, reflecting how power encompasses objects, concepts, and ideas, such as "emotional intelligence," which appears 43 times. While the knowledge map lists only three women, the power map features 10, offering a more balanced gender representation. The rankings remain intriguing and



Fig. 10. Power vs Knowledge Rankings.

Rank	Knowledge	Power	Pantheon Project
1	Rachel Carson	Nelson Mandela	Muhammad
2	Jane Goodall	Internet	Isaac Newton
3	Aristotle	Mahatma Gandhi	Genghis Khan
4	Wangari Maathai	Wangari Maathai	Jesus
5	Isaac Newton	Elon Musk	Leonardo da Vinci
6	Leonardo da Vinci	Martin Luther King Jr.	Ludwig van Beethoven
7	Charles Darwin	Printing Press	Aristotle
8	Albert Einstein	Rachel Carson	Plato
9	Alan Turing	Ada Lovelace	Marco Polo
10	Elon Musk	Tim Berners-Lee	Galileo Galilei

Table 4. Top 10 Comparison

subjective; for example, Sheryl Sandberg, former Chief Operating Officer of Facebook (Meta Platforms), ranks 14th in power, while Mark Zuckerberg, Facebook's co-founder, is 24th.

These rankings invite debate and are left open for readers to interpret based on their own value judgments. Notably, there is significant overlap between the two maps, with individuals appearing in both regardless of the topic. The gender balance and entity selection may partly reflect the timing of data collection: the knowledge dataset was compiled in July 2023, while the power dataset was created in October 2023. The discrepancies and variations could result from adjustments to the model during this three-month period.

5.5. Collective Centralities

The same method of analyzing named items can be applied to other dataset columns. The knowledge dataset comprises 1,166 fields, with food as the largest. Fields such as food, sports, and geography are far more represented than medicine, mythology, or nature. This raises questions about whether such discrepancies result from the abundance of related web content or biases in GPT-3.5's data modeling. One conspicuous absence from both datasets is pornography, despite comprising 12% of websites (Ahmed, Shafiq, and Liu 2016). Terms like "erotic" or "sex" appear only in specific contexts, such as Simone de Beauvoir's The Second Sex. This omission highlights the filtering processes shaping GPT's representations.

The map also reveals centralities within the network: while food and sports are peripheral, fields like geography, history, and politics form central clusters. In contrast, the power dataset emphasizes fields such as Economic Power (616 entries) and Social Power (593), whereas Architectural Power has only 23 entries. These discrepancies reflect the varied ways GPT-3.5 categorizes and prioritizes knowledge and power.

6. Outlook

Large language models have the potential to reveal overlooked truths about our reality. However, it is unlikely they will rewrite history with figures like Rachel Carson and Jane Goodall as its new central protagonists. This investigation seeks to establish a framework for holding these increasingly obscure systems and the transformations of large-scale collective datasets partially accountable.

The training and operation of machine learning systems demand vast energy and material resources, making rigorous economic and ethical scrutiny inevitable. What happens if the outputs of large language models are shaped not only by internet data and corporate adjustments but also by advertising influences? Currently, the mechanisms driving token selection remain opaque, raising concerns about potential misuse or abuse of this power.

The concept of *Artificial Worldviews* introduces a novel approach to scientific inquiry, leveraging the distorted lens of large language models. These systems generate datasets that extend beyond mere representation, embedding political, infrastructural, and corporate biases.

In this world, truth and certainty dissolve as computation, data, labor, and material forces remain in constant flux. The maps created

through this project visualize the complex interplay of these forces, offering a critical lens to examine the planetary scale of computational systems, their economic imperatives, and the hidden politics of inclusion and exclusion shaped by click work and model adjustments. By engaging critically with these systems, we can begin to illuminate their hidden dynamics and influence their future trajectory.

Note

Both can be viewed and downloaded here: https://artificial-worldviews.kimalbrecht.com/.

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The Dybbuk, The Loab, Latent Space and Multi-Modal Artificial Intelligence

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In 2021 Open AI introduced CLIP and VQGAN, neural network architectures for still and moving text-to-image models (Crowson 2021). Questions arose about how these algorithmic images were sourced, rendered and generated. *Language Is Leaving Me – An AI Cinematic Opera Of The Skin (LILM)* used a multimodal format, meaning "a ML (machine learning) model that is capable of processing information from different modalities, including images, videos, and text" (Google 2024). It examined the creation of images through the lens of epigenetic or inherited traumatic memories of cultures of diaspora and revealed a dystopic side in Stable Diffusion's prompt engineering and image-to-image capabilities, one of structural flaws and crucial biases. This paper examines AI's dystopic "digital twin" or unconsciousness that carries within itself what in Yiddish folklore is known as the "Dybbuk", a wandering spirit of a dead person possessing the soul of a living person, and in the AI, world is called the "Loab". It investigates the relationship between algorithmic rendering, latent space, epigenetic memory, selective inattention, and machine human cognition exploring new pathways.

1. Introduction

The embedded tagging systems commonly referred to as Large Language Models (LLMs) emerged around 2017 built on transformer models, meaning neural networks learning context or pattern recognition to understand predictive models of sequential data. AI models retrenched on using tagging systems for predictive textual taxonomic systems, but this is not as feasible for AI visual imaging systems. Data anonymized for privacy deletes many taxonomy focal points adding unnecessary noise to results. Large data models can be manipulated into reproducing parts of training data that were previously deleted (Vaswani et al. 2017). According to OpenAI, it is difficult if not impossible to prevent an opensource model for being used to cause inadvertent harm, as many input classifiers amplify bias This problem of unsafe or distorted content output is one of the thorniest problems in visual AI and one all major companies are scrambling to implement solutions for, with varying degrees of success (Roose 2023).

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Epigenetics is understood to mean chromosome modifications that are not part of DNA structures, and more specifically its rDNA (Felsenfeld 2014). It is not definitively proven that human psychological trauma can change chromosomal rDNA, much less human behavior. However, many psychologists understand trauma can be passed through generations and manifest in various ways (Hubl 2020). Intergenerational trauma is often non-verbal, cryptic, and difficult to decipher (Rosner 2017). I questioned if AI could comprehend my epigenetic trauma as an agnostic, third generation ethnic Jew from the Pale of Settlement in Eastern Europe, much less the epigenetic traumas of other cultures of diaspora. Examining emerging artificial intelligence synthetic image rendering and nascent cinema driven by Large Language Models (LLMs) within the context of epigenetic trauma, it took three years to develop "*Language Is Leaving Me* – An AI Cinematic Opera Of the Skin." (LILM). *LILM* was a performed cinematic installation partially powered by EMG human biometric measurements. A volunteer audience member had EMG patches placed on her face to monitor either a smile (positive) or frown (negative) response while watching the movie. Her reactions controlled the sonic environment for the entire audience.

I translated the movie's English language narration into Yiddish, Chinese, Tamil, and Xhosa cursive scripts processing them through both verbal (text prompt engineering) and visual (image-to-image) AI. The resulting multimodal movie revealed latent Dybbuks, hidden and devastating aspects of the algorithmic processes underlying transcultural LLMs. Algorithmic processing erased memory and distorted personal signified visual and verbal referents.

I did this to recreate and trace my usually unconscious memories stored inside my brain. I now want these images to be eventually fed back into even higher level AI systems and interacted with in real time by a performer. Translating my English language memories into four languages, I will fragment and decoupled their linguistic and visual semiotic significance concerning unexpressed trauma. The reason is AI purports to understand through linguistic and visual sampling the meaning of trauma, and other deep and formative human emotions, but in truth is incapable. The enhanced performance, currently a work in process, represents surrendering individual and collective memory to the unfolding age of AI.

2. Process and Journey – Discoveries and Challenges

In early 2021 into 2022 AI imagery consisted of CLIP (Contrastive Language-Image Pre-training) and VQGAN (Vector Quantized Generative Adversarial Network). Its images produced odd and phantasmagorical results. CLIP arose from investigations into zero-shot learning, natural language supervision, and multimodal learning. Zero shot learning means an AI model can understand and categorize objects and concepts without ever haven seen examples of those concept before. Natural language supervision analyzes speech and text in both grammatical correct and grammatically incorrect variations, and multimodal learning explores ideas through visual, sonic, perceived, written haptic and movement modalities.

VQGAN arose from previous text-to-image transfer models like AttnGAN (Attention GAN) and others (Xu et al. 2018, Radford et al. 2021, NerdyRodent 2021). CLIP decides which tagged captions VQGAN aligns best with so it can be assigned to a specific image generation. The CLIP model includes its own separate transformer architecture but does not generate anything itself. It deals with zero-shot learning datasets. This means a model can observe samples from information classes that were not included in the original training model (Larochelle et al. 2008). CLIP is open source, whereas other robust visual classification models like DALL-E, a diffusion model that used a different set of transformers and also developed by OpenAI were initially not opensource (Ramesh et al. 2022). Katherine Crowson refers to CLIP as the "Perceptor" or selector and VQGAN as the "Generator" meaning the generator of images. There are not smart discriminators for filtering information outside of common contemporary data harvesting techniques, another issue that contributes to skewered results. Though there has been rapid development of these techniques since 2021, many of the foundational problems still plague the field, which is why older models are referenced.

In 2021 I used the commercially available platform on the web, Night Café but dissatisfied with the results switched to the python language based solution, Google Colab. Since I am not a python programmer, I worked with volunteer software developers to use the early release Google Colab notebook "VQGAN+CLIP (with pooling).ipynb". I chose the English language prompt engineering word "queer" because during the late 19th century and early 20th century the British English vernacular meaning referred to someone who was odd or eccentric, such as the phrase "that's a queer fellow". In recent decades the meaning of the word queer has shifted in the global parlance to a more gendered and sexualized meaning.



Fig. 1. Chinese language examples

The Google Colab image datasets used Faceshq_5; ImageNet_10245; ImageNet_16394; OpenImages_8192_5; WikiArt_1024; and WikiArt_16384. All six visual datasets returned strikingly similar representations for the word queer. I did not understand why, since they had access to millions and millions of images through the six chosen data model sets. I used a fixed seed value of 42 for all the images. A seed value brings together a unique algorithmic mix of pixels, colors and shapes. Theoretically there are millions of seed values, though working with a fixed value allows images rendered across datasets to be more easily compared and standardized. Perhaps that is why the images resembled each other so much, but I thought that was too simple an explanation.

I added one other word to the text prompt, both “boy” and “girl” to see if anything changed. Again, the images were strikingly similar. I began testing the term using other scripted or character based languages that were not English. One of the programmers was Chinese and well versed in Chinese slang or colloquial vernacular terms. Google Translate was deployed for the strict Chinese translation of “queer boy” and “queer girl” and the Chinese native speaker input the slang variations that Google Translate would not know. We used the ImageNet 16384 image bank and the fixed seed value of 42. The results were shocking. Another programmer, this time from India spoke both Hindi and Tamil, so we tried the same experiment using those cursive scripted languages. The only difference was we used the COCO (Common Objects in Context) image bank, our seventh image bank also with the seed number 42. The results were even more outlandish. These image banks and their algorithms have subsequently been updated, reworked or had sections removed, but again the fundamental issues remain.



Fig. 2. Examples in Hindi and Tamil

2.1. Language Is Leaving Me

Experimenting with VQGAN, CLIP and Google Colab, though interesting produced unsatisfactory results for a creative project. Frustrated, in 2022 I returned to the basics producing a short video "Language Is Leaving Me" . The video used both original and archival copyright free footage to explore my epigenetic trauma as an agnostic Jew whose ancestors immigrated to the United States in 1906 from the Eastern European Pale of Settlement. Also, by 2022 huge advances had developed in the field of moving image AI cinema, spearheaded by the release of the opensource visual text-to-image model Stable Diffusion from Stability.ai. It used datasets from the LAION 5-B latent diffusion image bank (Schuhmann et al. 2022, Rombach et al. 2021). LAION-5B, created by the German charity LAION uses an aesthetic predictor, a numeric value indicating how much someone likes an image. Schuhmann states "4000 samples were annotated in a scale from 0 to 10 to be good looking or not". I found those definitions of the rating of aesthetic values by computer programmers, not artists, and not culturally comprehensive to be extremely problematic, especially after what I had discovered from my experiments using Google Colab with CLIP and VQGAN in Chinese, Tamil and Hindi. Simultaneously in 2022 AUTOMATIC 1111 introduced a web based graphical user interface that allowed both text-to-image and image-to-image scenarios (AUTOMATIC1111 2023). This made Stable Diffusion more accessible to artists. Running a series of tests, I worked with narrative translations of my original English language video in the cursive scripts of four languages: Chinese, Yiddish, Tamil, and Xhosa. I chose Yiddish because, it is the language of my ancestral diaspora, even though I neither speak nor read it. The other languages were chosen both for their geographic diversity and their original and fluid cursive scripts.

The biometric implementation of the sonic environment during the live performance received EMG input from the facial muscles of an

audience volunteer who viewed the movie alongside the audience. The EMG patch on their face registered a frown on their forehead (negative), or a smile on their cheek muscle (positive) to drive the sonic environment. The underlying sound was created by a sonic artist in Touch Designer and used a customized motherboard built in Shenzhen, China. The volunteer's reaction corresponded to the general reactions of the audience, with the sonic environment co-created at the time of the viewing between all participants. Though biometrics were important to the creation of the live performance I will not discuss *LILM's* human computer biometric interaction aspect in this paper.

3. Digital Twins – The Dybbuk and Loab in The Machine

During the development of *LILM* strange and malevolent images began appearing. This may have been influenced by the discussion and scenes of war, genocide, and disinterred corpses in my film, but they were not present all of the time. The batch processing in Automatic1111 using multilingual cursive scripts and image-to-image prompts kept generating human faces full of horror and fear, even when the prompts did not request or refer to this type of imagery at all. The algorithmic rendering process in Stable Diffusion evoked completely unintended digital twins' imagery that paralleled what in Yiddish folklore is the concept of the "Dybbuk" and in AI parlance called the "Loab". This discrepancy was enhanced during the subsequent performance installation involving a live volunteer audience interaction.

3.1. The Dybbuk – Ancestral Memories

A Dybbuk is the wandering spirit of a dead person possessing the soul of a living person it once loved. It eventually leaves its hosts body through an exorcism performed by a trained Rabbi. The mystic Isaac Luria (1543-72) is credited with establishing the belief in *dybbuks* through his doctrine of *gilgul* or the transmigration of souls. The word come from the Hebrew word ʔdibūq, קוּבִּיד meaning 'a case of attachment'. The idea of the *Dybbuk* became known to the general public with the publication *The Dybbuk, or Between Two Worlds* (Yiddish Der Dibuk, oder Tsvishn Tsvey Veltn), based on stories collected by S. Ansky who traveled to remote shtetls throughout the Pale of Settlement in Ukraine and Russia. In 1920 the book was turned into a wildly popular play produced in Yiddish in Warsaw, Poland and premiered on December 9, 1920 by the Vilna Troupe. The following year it was performed by the Hebrew language Habima theater in Moscow. In 1936 The *Dybbuk* was made into a movie by Mical Waszynski and is considered a classic of Yiddish cinema (Nashon 2021).

Through algorithmic rendering a digital twin or type of horrified Freudian id unexpectedly and mysteriously kept manifesting between the frames of my multi-lingual image-to-image video processing by Stable Diffusion. How could AI possibly be manifesting wandering spirits, or the souls of dead people culled from the archival and original source material I used? Over the three years of developing *LILM*, I deliberately avoided using the numerous commercial platforms available for visual AI. Instead, I painstakingly built my own workflows rendering experiments on servers based in Hong Kong, thereby avoiding many of the content restrictions pay-per-use customers of commercial platforms experienced.

3.2. The Loab – Artificial Intelligence Ghosts

On September 6, 2022 Steph Mai Swanson using the handle "Supercomposite" posted on Twitter, (now X) about the freakish results she was getting using an unnamed AI art commercial platform (Swanson 2022). Swanson was experimenting with negative prompts or "negative weighting" to shape an image of the actor Marlon Brando. Instead of her prompts rendering a look alike Brando, a horrific disfigured woman kept manifesting. Nonsensical characters spelling out "Loab" displayed alongside one of the renderings, so she called this phenomena "the Loab", stating, "Loab is the last face you see before you fall off the edge" (Coldewey 2022). The Loab became a social media sensation, but no one could explain exactly how and why it happened. Swanson called it a "combinations of optics and software". She then wrote an article about other deeply disturbing aspects of using AI, including how she coaxed it into creating an X rated BDSM (bondage, domination, sadism, masochism) relationship (Swanson 2023). At the time I was developing my own visual AI aesthetic I was unaware of Swanson's Loab, but our creative practices were uncovering similar issues of this lurking unconscious digital twin that seemed to span across linguistic and cultural divides.

4. Latent Space Births Unconscious Diabolic Digital Twins

Latent space is the key to understanding some of the mysteries in visual computer image rendering, especially for those not knowledgeable in computer science. This is because it is concealed, abstract, compressed, and muti-dimensional. In its essence its purpose is to encompasses internal or algorithmic representations of external events. In theory latent space contains mathematical models of all possible combinations of multiple renderings in a massive data set and can be shaped by using specific combinations of parameters.



Fig. 3. "They dug them up" – English archival footage and Chinese generated AI text-to-image and image-to-image



Fig. 4. "It was stories of the Jews of Azipute" – Tamil AI image-to-image generation and English language archival footage original

However, in fact it is just numbers collecting and processing different sample point numbers to output noise or vectors of numbers, which is why it is a strange concept for artists to grasp. The vectors, or intersection points are the range of possibilities for each latent variable and reach into the billions. All of these possible combinations take up a lot of storage space so in order to be used all the raw data needs to compressed to save space. This compressed space is coded and then decoded by different algorithms that calculate the differences and similarities between the sample points in space to render all that algorithmic noise into a coherent image. It is so exact that changing a model by just one number or seed changes the retrieval parameters and thus changes the output image. Usually similar combinations (i.e. types of birds, or types of cars) are mathematically lined up close to one another in latent space so they can be retrieved faster, but these parameters are prone to corruption. Algorithmic latent space representations fall apart even more when comparing multi-lingual text prompts in image-to-image batch comparisons. These comparisons seem to evoke a deranged digital twin appearing as the malevolent unconscious of the human psyche transculturally understood to be horrific or diabolic. It is the space where the Dybbuk or Loab is both concealed and emerges from. Latent space can't morph or transition from frame to frame with all details smoothly integrated, it can only use or pull the most prominent features of an image into the next rendered image. The hidden or dark side emerges because out of all of the billions and billions of images fed into the databanks, a percentages of those image are NSFW or Not Safe For Work. Like the exorcist needed to bring forth the Dybbuk, the NSFW images can be evoked and the "soul" released. I observed this very clearly by disrupting traditional algorithmic rendering formulas when I mixed cursive scripts of different languages into the multi-lingual text prompts alongside image-to-image comparisons. The algorithms gagged, either erasing my epigenetic memory entirely or producing horrific ghosts. Instead of trying to delete these apparitions, I incorporated them into my artistic practice.



Fig. 5. The original Loab courtesy Steph Mai Swanson via Twitter

Those who are capable of diving the mathematical formula of how and where to pull images from latent space become the conjuring magicians of the age of AI, usually unknowingly releasing both angels and devils. The same process that produces the digital twins of Loabs and Dybbuks also de-categorizes populations who histories are not digitized and taxonomized. This process is referred to as 'erasure' or "catastrophic forgetting" (Gebru and Denton 2024). The Dybbuk and the Loab are the deep, dark unconscious of algorithmic rendering processes, the imperfect and corrupted digital process of perfect, mathematical calculations (Katzman et al. 2023).

4.1. Evocations: Latent Space and Inattention Blindness Foment Visual Neglect



Fig. 6. The Juro or (Jew) Dybbuk manifesting from the Yiddish cursive script. English prompt “He breaks out those shinny things from that skull those teeth”. The characters etched on the faces were not prompted but spontaneously appeared.

Human visual perception registers information from 120 million rods and 7 million cones that flow from the optic nerve to the brain. The small optic nerve functions, or can be compared to a type of vector space compression system where the information is sent to and then biochemically decoded in the brain (Souza et al. 2024). This human compression system could loosely be compared to the visual systems own version of a latent space biological compression algorithm. Thinking in this way and can lead to the design of new artificial visual systems. However, there is a vast difference between algorithms and humans. Humans have presence in the real physical world and experience unpredictable moment-to-moment interactions. These interactions influence how they construct and remember their world. Within presence and unpredictability lies selective attention, or “inattention blindness” a term highlighted by the invisible gorilla experiment (Chabris and Simons 2011). In this experiment individuals were asked to pass a basketball between all members of a group. Their interaction playing the game was filmed. After the task was over, they were asked if they had noticed anything strange going on during the game. Approximately fifty percent of respondents said they had not seen anything unusual. When the film was played back to the entire group a person in a gorilla suit was clearly walking around in the middle of the game activity, visible for all to see. However, half of the participants had not even noticed it. Inattention blindness means only selected information, according to many factors is remembered by each individual. We are unable to recall every second of our life, but given the correct stimulus, we might evoke forgotten events deeply stored in the brain. As an example, most people remember their first primary school teacher but unless asked, never think about who that was and what they felt about their teacher. In the same way machine learning algorithms incorporates latent space using high level pattern recognition calculations. The Dybbuk or Loab can be thought of as the invisible gorilla in the suit. It mimics the selective inattention of algorithms that bring forth the unconscious aspect of human experience hidden throughout these large image banks when provoked, or in this case, evoked.

Meaning in the age of algorithmic smoothing, machine learning and data scrapping fosters semantic taxonomies that skewer mathematical algorithmic interpretations. This skewering is referred to as the ‘epistemics of training sets”, the fraught and complex relation between images and the concepts tying those images to their linguistic

meaning and that meaning to image tagging prompts (Cuzzolin 2021). Currently image tagging consists of nouns, with verbs and adjectives thrown in to enhance their meaning. Epistemic AI formulates new mathematical models for decision making. Its operating premise is that instead of inferring predictive models about the data it has at its disposal, it will assume it has a paucity of data from which to make any sort of conclusion. Only since 2016 has the issue of epistemic uncertainty in machine language become an area of focus. It acknowledges the difficulty of comprehending in domain and out of domain sampling that causes model formation to be insufficient. Another factor is the mundane human labor of images tagged by individuals whose first language is not English, and who lack the understanding and cultural nuances to comprehend what they are looking at. Paid by the word, it is advantageous for them to perform a cursory analysis of an image, tag and often mislabeling it, and move onto the next task at hand (Ruiz 2019, Crawford and Paglen 2019, Joler and Crawford 2018, Zhou et al. 2022).

Digital imaging systems traditionally process pixels on grids. Human visual perception reduces data from photoreceptors to the optic nerve. Metaphorically speaking they encodes image information into low bandwidth latent space representation suitable for processing by the human brain (Souza et al. 2024). Latent space can be reconfigured through optics and software into a generative model and these spaces are "extracted" from peoples and cultures who have no say in building them. Computer vision systems can produce outputs dehumanizing the other or just obliterate them, their existence and their culture. This ability is referred to as "catastrophic forgetting", a more nuanced view than erasure (Gebru and Denton 2024).

5. Next Steps

Language Is Leaving Me deals with epigenetic trauma of those who originated from the Eastern European and Russian Pale of Settlement, a trauma developed throughout millenniums. The geographic area is referenced at the beginning of the movie and the concept of Jews is rarely mentioned, yet the Yiddish Dybbuk appears nonetheless, summoning the ghosts of the dead. When *LILM* had its world premiere on October 7th, 2023 at the Copernicus Science Center in Warsaw, Poland the war in the middle east was breaking literally at the exact same moment, though no one was aware of it at the time of the showing. The cinematic performance installation recreated the epigenetic horror it was showing as the epigenetic horror was once again occurring in real time thousands of miles away (PBS 2025). The Dybbuks were in full force during the premier, evoked through the

latent spaces processes discussed above. What is epigenetic trauma if not the ultimate form of shock and attachment of all diaspora and war? It is an attachment so deep it changes the DNA and expression of rDNA of its host for generations to come. It inhabits the deepest latent space of human memory where it is often non-verbal and difficult to express, especially in cultures of diaspora.

My next steps involve using basic eye, hand and muscle coordination to invoke both real and artificial memories. I have begun using a computer to draw a series of stories about epigenetic trauma in the most simplistic manner, like that of a very young child. Using AI processing tools, the drawings turn into photographs and the photographs into short films. These films will be turned into audio reactive 3D Gaussian images interacting with a live performer. The memories will be interpreted through multiple languages and AI visual systems. These systems will highlight the *Dybbuk* or Loab, depending on the algorithmic rendering variables. There are various prototypes already in development facilitating these processes.

The aim of this process is to recreate and trace unconscious human memories stored in the brain. These images, through selective attention can be fed back into AI systems and interacted with by a performer, live time. The English language memories will be translated into four languages. At various times the languages will be fragmented so they lose their original meaning and associated memories. This is meant to illustrate epistemic ai decoupled from meaning and the underlying significance of felt but unexpressed trauma. AI purports to understand through linguistic and visual sampling the meaning of trauma but it cannot. The performance will serve as a representation against surrendering individual and collective memory, autonomy and agency throughout the unfolding age of AI.

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Between the Discrete and the Infinite: Attention and Latent Space Metaphors in Borges and Calvino

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Metaphors surrounding artificial intelligence increasingly inform contemporary discussions on the topic, shaping both technical conceptualizations and cultural narratives. This paper explores literary metaphors by Jorge Luis Borges and Italo Calvino, arguing that their narratives offer critical conceptual frameworks for understanding deep learning's representational structures. Drawing on five emblematic metaphors from Borges and Calvino—the Aleph (dimensional compression), the Library of Babel (combinatorial archive), the Chessboard (rule-based combination), the Atlas (emergent potential), and the Garden of Forking Paths (branching potentiality), this paper suggests that these literary metaphors reflect key phenomena within latent spaces and attention modules, such as the reduction of knowledge in one abstract point, dimensionality, and the combinatorial or potential logic. By aligning literary analysis with computational architectures, this paper highlights the significance of literary imagination in articulating deep learning's capabilities and limitations, challenging simplified or anthropomorphic interpretations.*

1. Introduction

> "The catalogue of forms is endless: until every shape has found its city, new cities will continue to be born." Calvino, Italo. Le città invisibili, 1978

> "The Library is total and its shelves record all possible combinations of the twenty-odd orthographic symbols" Jorge Luis Borges, La Biblioteca de Babel, 1954

The rapid proliferation of AI technologies has brought concepts like latent space and attention mechanisms to the forefront of technical and theoretical discussions. Melanie Mitchell observes that "metaphors are all we have for the moment to circle the black box" (Mitchell 2024). Indeed, from "neural networks" to "machine learning", metaphors are indispensable tools for grasping AI concepts. These metaphors, from stochastic parrots to agentive terms, reveal the scientific,

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political and cultural landscape of how we are trying to conceive artificial intelligence. Anthropomorphic and epistemic attributes sneak into AI discourse with human-like attributes, directing their interpretation, operationalization, design and deployment.[1] Yet, common metaphors can also oversimplify or anthropomorphize, potentially obscuring the underlying mechanisms and their societal implications.

This paper argues that a selection of literary metaphors from 20th-century authors Jorge Luis Borges and Italo Calvino (the Aleph, the Library, the Chessboard, the Garden and the Atlas) offer valuable tools for understanding and critically engaging with these computational concepts. Following Lakoff and Johnson's (1980) premise that metaphors structure our understanding, we use literary examples not merely as illustrations, but as conceptual lenses. Borges and Calvino, writing amidst the nascent ideas of cybernetics, explored themes of infinity, combinatorics, and the nature of reality in ways that resonate strikingly with current AI paradigms. Their works, often moving beyond realism, be it scientific à la Zola or even promethean à la Shaw (Greiner 1979, 45), use the material world as a catapult to immerse the reader into the fantastic. The fantastic here is not a mere escape from the material world but a vehicle to uncover the structure of possibility (possible aspects of reality in fiction). As readers, we are encouraged to explore multiple interpretations of an observed reality evolving through the fantastic. From a universe contained in a single point in The Aleph to the combinatory notion of the universe seen as a library, this metaphorical fascination to understand an expanding world and reality is not merely Borgesian, we see it also in Calvino's Invisible Cities, where cities are merely possible combinations.

While previous work has noted connections between Borges and AI (Bottou and Schölkopf 2023), this paper focuses specifically on how a selection of their metaphors illuminates the tension and interplay between *discrete, combinatorial* systems (attention mechanisms) and *continuous, generative* spaces (latent representations). We analyze five key metaphors selected for their distinct embodiment of this tension: Aleph (total compression) Garden of Forking Paths (concurrent potentiality), Library of Babel (combinatorial archive), Chessboard (rule-based combination), and Atlas (emergent forms from a potential field). The first literary metaphors in the essay concern world-building. The following metaphors explore a bifurcation of this world: the first presents a discrete universe of combinations of existing elements, and the second conveys a continuous world of potentialities.

By examining these literary metaphors and mapping them onto the concepts of latent space and attention, we aim to develop a richer

understanding of how AI models structure information and generate novelty. This comparative approach allows us to appreciate the capabilities of these systems while critically interrogating the limits, illusions, and biases inherent in their models of possibility. The paper proceeds by detailing each literary metaphor, then connecting these concepts to their AI counterparts, culminating in a discussion of the insights and critical perspectives offered by this juxtaposition.

2. Metaphors

We propose a selection of five metaphors from Borges and Calvino which help illustrate five substantial and distinct modes of grappling with the structure of reality and the universe of possibilities, oscillating between combinatorial logic and continuous potential.

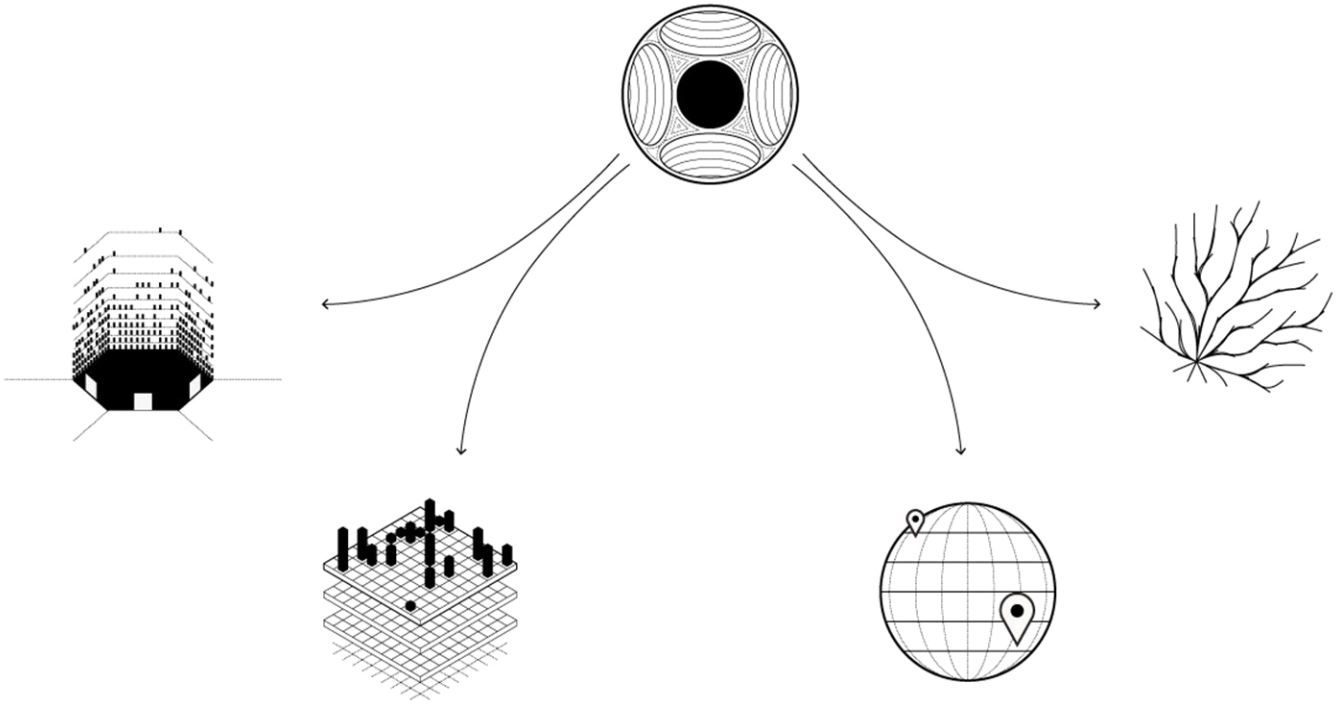


Fig. 1. Metaphors of the latent space. Starting from the top where the Aleph demonstrates the compression of reality to a point, on the left, the combinatorial discrete metaphors of library and chessboard appear. On the right, we present the continuous metaphors of the atlas and the forking paths.

2.1. The Aleph: Compressing Totality in a point of maximum density — or Dimensional Compression

Borges' concept of the Aleph as a point in space that contains all other points, has been studied also in literary terms (González Echevarría 1990, Manguel 1996), in mathematics and physics (Rucker 1984, Bohm 1980) and in computational perspectives (Deutsch 1997).

"El Aleph" (1949) is concerned with a radical perception of the compression of possibility: a single point containing all points. The story's central narrative suggests a world where totality exists in simultaneity, where the infinite is made finite without losing information. This concept aligns with Borges' broader narrative interests in infinity, labyrinthine structures, and the limitations of human perception and language. From a technical perspective, the Aleph works as metaphor

for dimensionality reduction and embedding spaces in modern machine learning. As, for instance, Mikolov et al. (2013) demonstrated with Word2Vec, complex semantic relationships can be compressed into dense vector representations where proximity stands or corresponds for meaning.

The Aleph starts with a narrator, who we later find out is the same Borges, visiting the family house of the late Beatriz Viterbo, a woman whom he loved deeply. We learn about this love through his several descriptions of his visits: in 1933 it rained profusely, in 1934 he presented himself with traditional Argentinian alfajores, and so on. It is in one of these visits that he meets Carlos Argentino Daneri, Viterbo's first cousin, described by the narrator as a mediocre poet, but the one who introduces the narrator to the Aleph residing in his parents' house, scheduled to be demolished: "In one corner of the cellar there was an Aleph. He explained that an Aleph is one of the points in space that contains all points". (Borges 1954, 635) The narrator, still believing Daneri to be insane, promptly proposes to see it immediately. Once the narrator is situated at the right spot in the basement in the darkness, he is able to see it: "I closed my eyes, then opened them. It was then that I saw the Aleph" (Borges 1954, 639).

The reader is then presented with a description that reveals a world where "(I) saw the Aleph from everywhere at once, saw the earth in the Aleph, and the Aleph once more in the earth and the earth in the Aleph," (Borges 1954, 643). This recursive vision suggests the reader not merely a vessel for all things, but a place where each part contains the whole. We could say that it presents a reality where locality and universality share the same space and become almost the same. The narrator's struggle to communicate what he sees in The Aleph shows a tension between reality, language and memory, and the way this last two can only convey so much: "I come now to the ineffable center of my tale; it is here that a writer's hopelessness begins. Every language is an alphabet of symbols the employment of which assumes a past shared by its interlocutors. How can one transmit to others the infinite Aleph, which my timorous memory can scarcely contain?" (Borges 1954, 640).

Nonetheless, the narrator tries to recreate with words what he sees: "The Aleph was probably two or three centimeters in diameter, but universal space was contained inside it, with no diminution in size. Each thing (the glass surface of a mirror, let us say) was infinite things, because I could clearly see it from every point in the cosmos" (Borges 1954, 641). He sees everything: "(I) saw all the mirrors on the planet (and none of them reflecting me)" (Borges 1954, 641). It rep-

resents an ultimate compression of the infinite into the finite, a recursive structure where each part contains the whole, challenging the limits of perception and language. The narrator struggles to describe this "ineffable center," highlighting the gap between holistic experience and linear language. This metaphor embodies the fantasy of total knowledge contained within a single, finite point, and echoes or resembles dimensionality reduction and vector embedding spaces in modern ML. Just as the Aleph contains "all the mirrors on the planet" while occupying merely "two or three centimeters in diameter," the bottleneck layer in variational autoencoders compress high-dimensional image data into compact latent representations without losing essential information (Kingma and Welling 2013). This information compression is particularly evident in multimodal embedding models like CLIP (Radford et al. 2021), which unifies visual and textual modalities in a shared latent space, allowing the model to "see" connections across different forms of data.

2.2. The Library (of Babel)

Borges' "La Biblioteca de Babel" (1944) has inspired extensive scholarly analysis across disciplines, from literary theory (Rodríguez Monegal 1978, Blanchot 1993, Eco 1995, Foucault 1966, among others) to mathematics (Bloch 2008, Rucker 1982, Dennet 1995) and computer science (Chaitin 2002, Lasswitz 2013, Dennet 2013). This metaphor of a universe composed of hexagonal galleries containing all possible books has proven particularly generative for computational thought.

"La Biblioteca de Babel" (1944) seems to present two worlds in one story. First, the idea of an infinite variation (the library) that starts with a limited set of elements (the books) and the idea of being lost in the whole world. The reader is presented with a description of this library as a universe and being lost in a book, in a combination of books, in the library, and in a way in the universe. The Library's architecture, opening the text, is presented as the main framework in the story. The narrator opens up the text by defining the Library as "The universe (which others call the Library) is composed of an indefinite, perhaps infinite number of hexagonal galleries" (Borges 1954, 252). Borges further elaborates on the contents of these galleries, creating an evocative impression of this metaphorical world:

> Twenty bookshelves, five to each side, line four of the hexagon's six sides; the height of the bookshelves, floor to ceiling, is hardly greater than the height of a normal librarian. One of the hexagon's free sides opens onto a narrow sort of vestibule, which in turn opens onto another gallery, identical to the first— identical in fact to all. To the left and right of the vestibule are two tiny compartments. One is for sleeping, upright; the other, for satisfying one's physical necessities. Through this space, too, there passes a spiral staircase, which winds upward and downward into the remotest distance. In the vestibule there is a mirror, which faithfully duplicates appearances. (Borges 1954, 252)

In an interview with Georges Charbonnier in 1965, Borges acknowledged the two central ideas in the story: the "possibility of almost infinite variation beginning with a limited number of elements" and "the idea of being lost in the universe, of not understanding it" (Greiner 1979, 45). The author makes sure to emphasize the Library's completeness and its infinity nature: "The Library is "total" – perfect, complete and whole – and that its bookshelves contain all possible combinations of the twenty-odd orthographic symbols (a number which though unimaginably vast, is not infinite) – that is, all that is able to be expressed in every language" (Borges 1954, 259). The story concludes when the narrator establishes that the Library is unlimited and periodic, creating in the reader not only a sense of infinitude but of repetition and order:

> I have just written the word "infinite." I have not included that adjective out of mere rhetorical habit; I hereby state that it is not illogical to think that the world is infinite. Those who believe it to have limits hypothesize that in some remote place or places the corridors and staircases and hexagons may, inconceivably, end—which is absurd. And yet those who picture the world as unlimited forget that the number of possible books is not. I will be bold enough to suggest this solution to the ancient problem: The Library is unlimited but periodic. If an eternal traveler should journey in any direction, he would find after untold centuries that the same volumes are repeated in the same disorder—which, repeated, becomes order: the Order. My solitude is cheered by that elegant hope. (Borges 1954, 268)

2.3. The Chessboard

Calvino's chessboard metaphor from "Invisible Cities" is a foundational metaphor where the board becomes a "model of combina-

torial reasoning", a discrete space where meaning arises from the rule-bound arrangement of symbolic pieces. It has been analyzed primarily in terms of its combinatorial and rule-based aspects, the "the tension between the visual and the verbal" (Ricci 2001), as a precursor to hypertextual and procedural literature (Aarseth 1997). The author's broader engagement with scientific concepts, particularly cybernetics and information theory (Pilz 2003) and how its system of "constrained combinations" resembles attention mechanism in machine learning (Mitchell 2024).

Calvino's "Invisible Cities" (1978) narrates an imagined dialogue between the Mongol emperor Kublai Khan and Marco Polo, a Venetian merchant. Every evening, in the gardens of the imperial palace Xanadu, Marco Polo describes to the Great Khan the cities of his empire. The narration progresses as an inward journey into understanding the patterns and underlying logic of the cities of the empire. At the heart of the book lies a tension between two opposing forces. Kublai Khan embodies a modernist desire for order and system – a cartographic impulse to grasp the empire in its totality. Polo, in contrast, represents an errant counterforce: his stories refuse stable meaning, instead emphasizing fragmentation, exception, and plurality. This dialectic – between structure and singularity, system and deviation – has been widely explored in Calvino criticism (Cannon 1991, Pilz 2003, Panigrahi 2018). Pilz (2003, 229-242) describes Calvino's attitude as simultaneously a force seeking a global structure in the labyrinth and one fascinated by the same labyrinth. Following Umberto Eco's (1984, 7-12) distinction of the three types of labyrinths into the linear, the maze, and the net, Calvino's attitude stands in between the multicursal, tree-like maze of modernity and the Deleuze and Guattari's rhizome (1987). The visual metaphor of a chessboard, introduced in the penultimate chapter of the book, shows this hybrid process:

> Marco Polo, mute informant, spread out on [the majolica floor] the samples of the wares he had brought back from his journeys to the ends of the empire: a helmet, a seashell, a coconut, a fan. Arranging the objects in a certain order on the black and white tiles, and occasionally shifting them with studied moves, the ambassador tried to depict for the monarch's eyes the vicissitudes of his travels, the conditions of the empire, the prerogatives of the distant provincial seats. (Calvino 1978, 121)

Here, the chessboard becomes more than a stage for storytelling, it is a model of combinatorial reasoning. Wilson (1992, 91) defines the

chessboard as the “emblem of cities that emphasizes patterns and space”. The chessboard formalizes the cities into black-and-white discrete combinations of entities. The space of a city deconstructs into a mental space, – akin to Baudrillard’s oneiric space (1988) – in which the mind can create by decomposing the elements and recombining them. Using metaphoric wares found during his travels and arranging them in a particular combination, the merchant can describe the cities in the empire. In this passage, Calvino, similarly to “Castello dei Destini Incrociati” (1973), uses visual props – in the former case, tarot cards, in this case, wares from the travels – as visual concepts for combination. In “Cibernetica e Fantasmi” (1995, 8), Calvino advocates for the possibility of understanding language through dismantling and reassembling words. In this passage, the entity is more complex; instead of combining words, meaning is created through a combination of visual symbols.

After contemplating the chessboard, Khan realizes that not every arrangement is possible but that, playing by the rules, one could create countless combinations. The discrete space of combinations of the chessboard, albeit unsatisfactory, is revealed to be a creative structure. Its limits serve as the constraints that stimulate creativity, reminiscent of the theoretical investigations by the experimental literary group Oulipo, of which Calvino was a part for some time. Using constraints to stimulate creativity – in this case, the rules of chess – elements of reality can be recombined to create the inexistent, whereby even a few combinations – as in the chess pieces – can be recombined in near-infinite realities. In the same spirit, Raymond Queneau, one of the founders of Oulipo, in the book “Cent Mille Milliards de Poèmes” (1961), features 10 poems of 14 lines cut at every line. The reader can choose a combination of the 10 poems and 14 lines to read; these combinations total 10^14 possible poems.

2.4. The Atlas

The metaphore of the Atlas has attracted research from multiple disciplines. Authors like Vrbančić (2012) have identified it as a comment on the unattainable “dream of the perfect map” and the limits of representation, contrasting cartographic reason with postmodern disorientation. Others like Rita Wilson (1992) used it in urban theory to explore how cities are perceived and experienced, shaped by memory and narrative beyond physical structure.

It is in the last chapter of “Città invisibili,” Calvino presents the book’s final metaphor: Kublai Khan’s atlas.

> The Great Khan owns an atlas where all the cities of the empire and the neighboring realms are drawn, building by building and street by street, with walls, rivers, bridges, harbors, cliffs [...] The atlas depicts cities which neither Marco nor the geographers know exist or where they are, though they cannot be missing among the forms of possible cities [...] The atlas has these qualities: it reveals the form of cities that do not yet have a form or a name. (Calvino 1978, 135-138)

At first glance, the atlas seems to fulfil the emperor's modernist dream: to contain the empire within a single, exhaustive object. Ryan (2016, 222–237) interprets the atlas as a hegemonic metaphor for Kublai Khan's desire for control. As the Mongol emperor, Khan is comforted by the possibility of reducing his whole reign to one object. This almost magical object is reminiscent of an encyclopaedia of spatial knowledge, in accordance with Calvino's appreciation of the Enlightenment (Pilz 2003). At first a hegemonic, non-expandable cartographic terrain, the metaphor suddenly opens possibilities for transgression (Ryan 2016). It contains not only all the cities that have existed and exist, but all the possible cities, as every form can reveal a city. Wilson (1992, 91) defines it as the metaphor "emblem of other patterns and worlds". As Calvino attempts to offer a memory structure, the fluidity of the cities escapes any possible hegemony overthought.

Unlike the previous metaphors, no stable entities exist for the forms composing the cities. The combinatorial reality is not comprised of parts but instead of a state of flow. Calvino abandons structural closure in favor of infinite generativity. The city is no longer an object but a process, a constellation of flows, temporalities, and potential arrangements. The shift from chessboard to atlas marks a critical movement in the book: from the finite to the infinite, from constraint-based recombination to endless potentiality ("The catalog of forms is endless: until every shape has found its city, new cities will continue to be born," Calvino 1978, 138).

2.5. The Garden (of Forking Paths) or the Labyrinth

In "El jardín de senderos que se bifurcan" (1941) ("The Garden of Forking Paths"), Borges introduces a spatialized structure that represents the complex nature of time, choices, and potentiality. This metaphor captures the fundamental idea of branching trajectories that are divergent yet co-existing narratives and outcomes, and which are central to literary as well as to computational explorations of complexity.

Recent labyrinth theory (Kern 2000, Hennig 2015) offers insights into how the figure of the labyrinth functions not just as a narrative device, but as a semantic structure that actively organizes experience, disorients and reorients, and compresses and expands temporal and spatial dimensions. Henning emphasizes labyrinths as semantic spatialities that work as topologies of meaning where the navigation becomes an interpretative act. In this light, Borges' garden as a metaphor for multiplicity can be seen as a semantic topology which echoes latent space. Each decision, each sampling operation whether in a diffusion model (Ho et al. 2020, Song et al. 2021) or reinforcement learning (Silver et al. 2018) unfolds a new branch of potentials or possible states. In diffusion models, each generated image is a trajectory through a noise saturated space towards a possible that is instantiated, and where all the possible trajectories starting from the initial noise are contained in that initial point.

Moreover, labyrinths in literature act often as epistemological devices reflecting tensions between: 1) totality and disorientation, as in Danielewski's "House of Leaves" (2000), where the house is a constantly shifting physical impossibility that functions as an unmappable and generative spatial latent manifold), 2) structure and opacity, as in Dürrenmatt's "Minotaurus" (1985), where the minotaur is trapped in a mirror maze that reflects many images of itself where it cannot recognize itself; and 3) knowledge and its limits, as in Lovecraft's "The Festival" (1925) where architecture of the unknown becomes a pathway to knowledge, but at the cost of madness.

In Borges' work, the labyrinth garden is framed by the encounter of Yu Tsun and Stephen Albert, which is also framed by a spy story, forming a story-within-a-story-within-a-story. Borges tells to Charbonnier: "I think that the two ideas are behind its origin: the idea of the labyrinth, which has always haunted me, and of the world as a labyrinth, and also the idea of a man who kills a stranger to attract someone else's attention to himself ... I believe that what is more important than the detective story is the idea, the presence, of the labyrinth, and after that of a lost labyrinth. I amuse myself with the idea, not of losing oneself in a labyrinth, but in a labyrinth which also loses itself" (Greiner 1979, 45). The garden then serves as a structure for understanding the universe, as the narrator writes, "The garden of forking paths is an incomplete, but not false, image of the universe" (Borges 1954, 290). This concept of branching paths can be seen as an exploration of the difficulty of decision-making and the multiple directions that stem from each choice we make, of finding a path and, at the same time, being lost in another.

The narrator continues to elaborate this idea by contrasting it with a traditional, linear understanding of time: “Unlike Newton and Schopenhauer, your ancestor did not believe in a uniform, absolute time; he believed in infinite series of times, a growing, dizzying web of divergent, convergent, and parallel times” (Borges 1954, 290). Borges gives us a complex understanding of time, where multiple paths and possibilities can coexist and intersect, creating layers of potential trajectories and outcomes.

Throughout the story, the narrator emphasizes the concept of multiple trajectories and the simultaneous existence of various potentialities. He writes, “in all fictions, each time a man meets diverse alternatives, he chooses one and eliminates the others; in the work of Ts’ui Pên, the character chooses – simultaneously – all of them” (Borges 1954, 286). This idea challenges the notion of singular, linear narratives and instead presents the reader with a world where all possibilities are happening at the same time. Borges further explores the implications of this multifaceted understanding of time and existence: “we do not exist (in the same time); in some, you exist but I do not; in others, I do and you do not; in others still, we both do” (Borges 1954, 290).

Despite the labyrinthine nature of the garden and the endless possibilities it seems to represent, Borges suggests that there are moments of convergence: “Once in a while, the paths of that labyrinth converge” (Borges 1954, 286). Thus, the reader is presented with the idea that there are points where different trajectories intersect and align, creating spaces of multiple moments of unity and coherence.

3. Attention Module and Latent Space

Stimulated by a fascination for the possibilities surrounding reality, all the metaphors introduced begin from the key assumption that the world of possibilities can be stored and structured in a finite object: Aleph’s point, a library, a chessboard, an atlas, a garden. The structure can be achieved in two ways: it can stem from the near-infinite combination of discrete entities, i.e., books in a library, parts of a book, chess plays, or it can be continuous, a space of potentiality, where every form can become a city, and every trajectory can be traversed. In this section, we suggest that these modalities are relevant to date as they mirror the most widespread structures to represent information in deep learning models. We claim that they loosely reflect on the one hand, the combinatorics of attention modules and, on the other, the continuity of the latent space. In this section, we walk through the latent space and attention module and discuss how these metaphors contribute to their understanding and mental images.

Due to the visual nature of the metaphors and the richness of their symbolic registers, we focus on generative vision models and their internal representations. In computer vision, the latent space refers to the part of the model where information is most compressed and semantically organized. In discriminative models, such as convolutional neural networks like ResNet (He et al. 2016) or EfficientNet (Tan and Le 2019), it is typically the space formed by the activations at the final layers before classification, those layers where the model distills complex perceptual data into minimal semantic representations. In generative architectures, the latent space takes on a more explicit role: in variational autoencoders (VAEs) (Kingma and Welling 2013), it is the bottleneck through which the input is encoded before being reconstructed; in StyleGANs (Karras et al. 2019), it becomes the starting point from which high-resolution and controllable images are synthesized.

Generative Adversarial Networks (GANs), autoencoders, and related models all share this principle: a compressed, abstract space from which images are uniquely derived. The position within this space (almost) fully determines the generated output. A point in this space can be manipulated and interpolated, and small changes in its coordinates can produce smooth and semantically meaningful transformations in the generated image. This space is often understood as continuous, multidimensional, and semantically rich, a geometry of meaning that reflects not the world as it is but the world the model has seen. Schaerf (2024) describes them as spaces that fill the gap between what exists and what could exist in between: the potential. Concurrently, Meyer (2023) equates them to an archive: a structure that organizes knowledge univocally and efficiently.

While this continuity is an illusion – since a model is a discrete entity on a discrete computing machine – the created representations can be continuously explored following infinite trajectories. Because of its complexities and affordances, this entity is often misunderstood and overhyped. The metaphors introduced above can help understand and situate the nature and expectations of this space.

Borges' Aleph conceptualized the possibility of infinite knowledge condensed into a single geometric point. In latent spaces, the visual, linguistic, and semantic information from billions of training data is compressed into a point that lacks physical extension but holds an extraordinary representational capacity. The Library of Babel offers a parallel: an archive of all possible books, where the real and the inexistent books are organized in the same formal structure. Likewise, the latent space encodes not only what is real, but what could be real.

Like a game of chess, its formation follows discrete steps across layers – through each layer's weights – a sequence of contingent moves that ultimately determines where the input will be placed within the latent topology.

The Atlas metaphor serves as a poetic analogy for this structure. Kublai Khan's atlas maps not only what exists but what might exist – forms awaiting instantiation, cities without names. Similarly, in the latent space, every point can be decoded into a visual form, even if that form has never been seen before. The space becomes a cartography of potential, where each direction signifies a journey that might be taken but has not yet occurred. The Garden of Forking Paths captures the final illusion of the latent space: that all these paths can coexist, that all these realities might simultaneously unfold. Nevertheless, as Borges reminds us, "The garden of forking paths is an incomplete, but not false, image of the universe" (Borges 1954, 290). The latent space, too, is always a partial view, a simulation of possibility constrained by what was seen, selected, and counted.

No latent space, however seamless, can represent the world's fullness. As models are trained on selective, biased, or censored datasets, so too are their spaces of representation partial, skewed, and incomplete. The latent space acts as a lens, reflecting not of an objective truth, but a filtered reality shaped by its training data. In this way, the data echoes Venice in Le città invisibili: always present behind Polo's imagined cities, constantly shaping what can be told, even if never mentioned directly. Just as the reader in Babel's library is also its author, the latent space reflects the gaze of its creator, even as it pretends to transcend it.

Contemporary generative vision models such as diffusion models – Stable Diffusion (Rombach et al. 2022), DALL·E 2 (Ramesh et al. 2022), and Imagen (Saharia et al. 2022) –, or visual autoregressive models – DALL·E 1 (Ramesh et al. 2021), VQ-VAE-2 (Razavi et al. 2019), and ImageGPT (Chen et al. 2020), – move away from a single high-level latent vector representation. Diffusion models are built around iterative, non-compressed, non-continuous generation pipelines, such as diffusion processes, which begin with pure noise and progressively denoise toward a coherent image. Similarly, visual autoregressive models construct images iteratively, token by token, predicting each patch based on the preceding ones in a causal sequence. The generative process emerges over time shaped by a schedule in diffusion models or a causal chain in autoregressive ones. Each step in the sequence represents a decision, a branching, a subtle turn. The process is not unlike Borges' Garden of Forking Paths: at every stage, a fork, a

narrowing, a divergence that might eventually lead, perhaps paradoxically, to the same image or to one entirely different.

Most of these models adopt a visual transformer architecture (Dosovitskiy et al. 2020), where the image is broken into patches and processed through layers of multi-head attention (Vaswani et al. 2017). This attention mechanism, first introduced by Bahdanau et al. (2014), is combinatorial in nature: it learns how each part of the input interacts with every other part. Attention is not merely a tool for computation; it is a structural metaphor. Like the chessboard or the library, it defines a grid of possible interactions. Technically, this is done by projecting each token into three distinct vectors, query (Q), key (K), and value (V), and calculating the attention weights based on the similarity between queries and keys. These weights are then used to blend the values across the entire input sequence. In this way, each token dynamically reshapes its meaning by selectively attending to others, creating an intricate mesh of mutual influence. Like Calvino's chessboard, it defines a finite, rule-based space within which tokens interact according to abstract patterns. On the chessboard, each piece has a form and a function, and its role emerges not in isolation but through its possible movements and relationships to others. Similarly, in a vision transformer, each token (often representing a patch of an image) can be understood as a conceptual unit, not unlike a piece in a game. Its significance is not determined in advance but arises from its combinatorial alignment: how it positions itself in relation to others through the attention mechanism.

The visual concepts become especially apparent in personalization methods such as DreamBooth (Ruiz et al. 2022). DreamBooth fine-tunes a generative model to bind a specific identity – a visual concept – to a synthetic token (often a rare word like "sks" or "zxxperson"), which the model learns to associate with the visual concept of the new subject. This token, embedded within the language and image spaces, functions like a chess piece that has been introduced to the board: its role is undefined at first, but it quickly acquires meaning through its interactions with other tokens—through the K/Q/V matrices that allow it to "understand" and be understood within the architecture. Each token participates in an economy of meaning: it attends, it is attended to, and it reshapes the meaning of the whole in the process. Attention, like Calvino's wares arranged on the tiles, is a mechanism for visual storytelling through relational structure.

Like Calvino's work oscillates between the modernist desire for structure – the tree-like, branching labyrinth that seeks to contain meaning within a coherent system – and the postmodern realization

that such structures are always provisional, always partial, so do the architectures of contemporary generative models. On the one hand, they are built upon hierarchical, layered structures, with each layer processing the data more abstractly. On the other hand, their networked nature, especially in attention-based architectures, reflects a rhizomatic logic, a system of mutual influence with no clear origin or center, where meaning is not inherited top-down but assembled laterally and contextually. Despite its complexity, it remains a structure bounded by its own assumptions, trained on partial realities, encoded in discretized weights. The rhizome, as Deleuze and Guattari propose, allows for multiplicity, rupture, and growth in every direction. But even the most rhizomatic models struggle to represent evolving, dynamic realities; they remain anchored to the training set, unable untangle from what they have seen. They offer a partial view of the world, one framed by human curation and algorithmic filtering. They are architectures of imagination but also of limitation, where their illusions of infinite recombination often obscure the finitude and contingency of their source.

4. Discussion

The long-lasting fascination in 20th century literature, particularly in Borges and Calvino, with the idea of structuring infinite possibility through metaphors of either combination of discrete elements (the Library, the Chessboard) or continuous potential (The Aleph, the Atlas and the Garden) finds parallels in the architectures and conceptualizations of contemporary AI models. Attention mechanisms, with their focus on relational interactions between tokens, echo combinatorial systems, and latent spaces in generative models evoke notions of a continuous and explorable continuity.

However, employing these literary metaphors is not about finding direct equivalences, but about using them as critical lenses to understand the potentials, limitations and tensions in deep learning and the way it represents and generates realities. Some crucial distinctions must be made. The literary metaphors of the Library, Chessboard and arguably also the Atlas function as diagrammatic tools, that is to say, as spatial arrangements or conceptual compositions that are understandable and navigable by humans, and which facilitate reasoning through or via visual organizations (Krajewski and Krapp 2011). In constrast, latent spaces exist in hundreds or thousands of dimensions and are fundamentally inaccessible to direct human perception or navigation. It is, rather, a statistical construct, only graspable through projections and approximations. Recognizing this difference is vital: these literary metaphors can illuminate the struc-

ture of possibility encoded in deep learning, but they simultaneously warn against mistaking the map (our conceptual grasp) for the territory (the inaccessible computational reality). Therefore, we use these metaphors not as a direct equivalence but as a valuable framework for a critical and reflexive engagement.

Within this fascination with the idea of structuring infinite possibility resides an unsolved and pervasive tension between the conception of novelty as either arising from a recombination of smaller components (as a resampling of pieces) or from a continuous space (exploration). This tension can arguably be traced back to the scientific revolutions happening around the turn of the century such as quantum physics, the theory of relativity and the emergent computational paradigms (Turing's universal machine, Shannon's information theory, and the birth of cybernetics), which, translated into the world of culture, seemed to suggest that reality might be better grasped as a vast interconnected network, a labyrinth of branching pathways and combinatorial permutations. Borges, Calvino and the later members of the Oulipo group acted as literary seismographs, presenting imagination as an experimental, even an algorithmic engine, capable of generating alternative realities. A crucial distinction emerges in how these infinite spaces are conceived: Are we dealing with a combinatorial explosion of possibilities, or with a continuous field of potential?

Many literary metaphors from these authors elaborate on discrete and combinatorial constructs: the Library is enacted through the exhaustive rearrangement of finite alphabets; the chessboard encodes an infinity of intricate urban configurations made up of a limited catalogue of elements; and also by Calvino, the Atlas, promised as cartography of continuous potential while being instantiated in discrete examples, while Borges' Forking Garden of time goes back to a fluid, continuous and perhaps elusive notion of possibility.

This oscillation between, on the one hand, the combinatorial and discrete, and the continuous and endless on the other also echoes how modernist and postmodern sensibilities fed with uncertainty, subjectivity, and the rejection of linear narratives, gradually shifted from the enumerative and combinatorial, towards the more ambiguous, open-ended infinite geographies of possibility that characterize later periods. In a seemingly parallel manner, in AI, systems of combinations alternate and coexist with representation spaces. "The excitement of working with artificial neural nets...comes in part from the fact that their 'knowledge' is distributed and emergent, a pattern of responses that often cannot be predicted beforehand" (Hayles 1999, 175).

Somaini, in his contribution to "Questionnaire of Art and Machine Learning", says that latent spaces are not unbounded fields, similarly, Borges characterizes the forking garden as "incomplete but not false" resonating with the fact that deep learning models capture a coherent logic, a kind of self-consistent system derived from the data they have ingested. But also, they omit, distort, or are blind to data and phenomena they have not seen or witnessed. As latent spaces and attention modules cannot be represented in reality due to their high dimensionality, they are statistical abstractions derived from data that we can only grasp through their projections into human-interpretable dimensions (Rodríguez-Ortega 2022). Latent spaces and attention mechanisms reflect filtered, biased realities shaped by training data and architectural choices, much like Polo's descriptions are inevitably shadowed by Venice. These literary metaphors, steeped in paradox and the limits of representation, thus provide a powerful vocabulary for articulating the inherent partiality and situatedness of AI knowledge, moving beyond simplistic notions of objective representation.

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Notes

+ indicates equal contributions.

***** This paper is complemented by a visual narration of the metaphors, that can be found on https://dvstudies.github.io/metaphors-of-latent-space/.

1. University of California, San Diego professor Sean Trott has discussed and sketched out the structure of the most used metaphors to describe LLMs. See: https://seantrott.substack.com/p/what-we-talk-about-when-we-talk-about.

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Material Agency in Systems of Art: Reflections on Theatricality, System Aesthetics, and Nonhuman Turn

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This article explores materiality within contemporary art practices, focusing on its historical and theoretical significance in the 1960s and 1970s, particularly in Minimalism and System Aesthetics. It examines Michael Fried's critique of theatricality in Minimal Art, Rosalind Krauss's response emphasizing phenomenological presence, and Hal Foster's focus on institutional critique. These critiques, along with System Aesthetics as developed by Jake Burnham, are analyzed in relation to the technological, ecological, and social context of the time frame in artworks. The study also considers how materiality is embodied in the work of Hans Haacke and Pierre Huyghe, whose practices engage with physical, biological, and social systems. Drawing on Francis Halsall's interpretation of Latour's "Quasi-Objects" and Flat Ontology, the article discusses how material agency in art reflects dynamic interrelations between human and nonhuman elements. It further explores how this engagement with materiality aligns with nonhuman turn theory, addressing the philosophical reflections of the human subject's role within political ecological systems. The article argues that material agency in contemporary art provides a critical force in understanding system-based practices, challenging traditional human-centrerd perspectives.

1. Introduction

This article examines the evolving role of materiality in contemporary art practice through the lens of system aesthetics, focusing on the theoretical and practical developments that emerged from Western Minimalism and systemic art practice in the 1960s and 1970s. During this period, significant shifts occurred in understanding the relationship between material objects, technological systems, and artistic practice. These changes reflected broader transformations in how artists and theorists conceived of the interaction between artworks, viewers, and their environmental contexts.

The investigation begins with a critical examination of the debates surrounding minimalism and theatricality. Michael Fried's seminal critique of minimalist art identified a fundamental shift away from modernist aesthetics, particularly the Greenbergian emphasis on

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medium specificity. This departure, which Fried characterized as a problematic turn toward theatricality, sparked important theoretical responses. Rosalind Krauss's counterargument emphasized the phenomenological aspects of artistic presence, suggesting that the viewer's temporal and spatial experience constitutes a crucial element of the artwork's materiality. Hal Foster further expanded this discourse by connecting these formal considerations to institutional critique, arguing for a return to social and political engagement in artistic practice.

These theoretical frameworks provide a foundation for understanding the emergence of system aesthetics, as articulated by Jack Burnham. Burnham's perspective, developed against the backdrop of cybernetic theory and technological advancement, offers insights into how artists began to conceive of their work in terms of systems rather than isolated objects. This systemic approach to art-making finds contemporary expression in the works of artists like Hans Haacke and Pierre Huyghe, whose practices engage with physical, biological, and social systems. Their work demonstrates how material agency operates within complex networks of human and non-human elements.

The article extends this analysis by examining how material agency manifests in contemporary art practices that integrate technological and ecological systems. Drawing on Francis Halsall's interpretation of Bruno Latour's concept of the quasi-object and flat ontology, we consider how these artistic practices challenge traditional understandings of materiality and objecthood. This theoretical framework helps illuminate the ways in which contemporary artworks function as sites where material, technological, and social systems intersect and interact.

Through this investigation, the article argues that material agency in contemporary art practice serves as a critical force that questions conventional assumptions about human subjectivity and technological systems. This perspective not only builds upon earlier critiques of theatricality but also engages with current discussions in the Nonhuman turn (Grusin 2015) and political ecology. The temporal dimension of material agency, as revealed through artistic practice, suggests new ways of understanding the relationship between human perception, technological systems, and environmental processes.

2. Theatricality and Objecthood

The 1960s and 1970s marked a shift in contemporary art, with Minimalism challenging traditional notions of objecthood and materiality. Michael Fried's critique of Minimalist art centered on its theatricality, arguing that the movement's focus on the viewer and space undermined the purity of the object. However, this perspective was questioned by critics like Rosalind Krauss and Hal Foster. Krauss argued that theatricality in the work emphasizes the role of context and viewer interaction in understanding art. Foster contended that art should destabilize belief and question institutional norms rather than affirming them. This section explores the debates between Fried, Krauss, and Foster, illustrating how theatricality became a crucial tool in rethinking the relationship between art, the viewer, and broader socio-cultural contexts.

2.1. Theatricality by Michael Fried

It was against this backdrop of artistic transformation that Michael Fried wrote his seminal essay "Art and Objecthood" (1967) (Fried 1998a), which critically examined the relationship between art and objecthood at a moment when art was breaking free from its traditional material constraints. Building upon Clement Greenberg's formalist aesthetics, Fried developed a critique of Minimalism "aspires not to defeat or suspend its own objecthood, but on the contrary to discover and project objecthood as such (151)." While Minimalist art (or "literalist art" in Fried's terminology) seemingly aligned with Greenberg's modernist logic of medium specificity, Fried argued that it fundamentally deviated from this trajectory. Where modernist art sought to overcome the limitations of its medium while maintaining medium specificity, Minimalist sculpture, in Fried's view, lacked the requisite "seriousness" by directly emphasizing its physical form and attempting to become purely object, thereby negating its medium specificity (155).

Fried acknowledged Minimalist sculpture as an outgrowth of modernist painting but considered it a misguided development. He argued that Minimalist works not only compromised their medium specificity through an emphasis on objecthood but also achieved a kind of "non-art" presence through their scale and structural relationship to exhibition spaces. Fried termed this presence "theatricality," describing theater as "the common denominator that binds together a large and seemingly disparate variety of activities, and that distinguishes those activities from the radically different enterprises of the modernist arts (164)." This theatricality mani-

fested in two crucial ways: first, in Minimalism's theatrical mode of presentation, with its acute attention to the viewer's encounter with works in actual space and its pursuit of *mise-en-scene* effects (Fried 1998b, 40); and second, in its demand for a new mode of reception analogous to theatrical experience.

Fried countered this theatricality with the concept of "presentness" in modernist art. He argued that while Minimalist Art demanded an experience of "endless duration," modernist works achieved a state of complete manifestation "at every moment (Fried 1998a, 166)." This distinction between temporal duration and instantaneous presence became central to his critique. As Fried articulated, "the experience in question persists in time, and the presentment of endlessness that is central to literalist art and theory is essentially a presentment of endless or indefinite duration." This temporal aspect of Minimalist art, in Fried's view, fundamentally opposed modernist art, because they are "at every moment the work itself is wholly manifest." He further claims,

> It (modernist art) is this continuous and entire presentness, amounting, as it were, to the perpetual creation of itself, that one experiences as a kind of instantaneousness, as though if only one were infinitely more acute, a single infinitely brief instant would be long enough to see everything, to experience the work in all its depth and fullness, to be forever convinced by it[...]it is by virtue of their presentness and instantaneousness that modernist painting and sculpture defeat theater...the condition, that is, of existing in, indeed of evoking or constituting, a continuous and perpetual present[...]. (167)

This notion of instantaneousness can be seen as an idealized conception of time, with Fried's critique of theatricality appearing to defend a Greenbergian idea of "purity" (Greenberg 1982). By insisting that each artistic medium should adhere to its inherent properties, this perspective seeks to establish artistic quality through formal autonomy. However, this framework was soon challenged by emerging artistic practices and theoretical discourses, particularly those theatricality practices and performance art centered on the experience of duration.

2.2. Critiques by Krauss and Foster

The theoretical landscape of the 1970s, characterized by new avant-garde movements and critical discourses, rendered Fried's position increasingly untenable. Rosalind Krauss, in her text "Mechanical Ballets," directly challenged Fried's assertion that theatricality

necessarily undermined sculptural integrity (Krauss 1981). She developed an understanding of how theatrical elements in contemporary sculptural practice, arguing that theatricality served as a critical tool for investigating and reconstructing the fundamental nature of sculptural enterprise:

> But the sculpture I have just been talking about is predicated on the feeling that what sculpture was is insufficient because founded on an idealist myth. And in trying to find out what sculpture is, or what it can be, it has used theater and its relation to the context of the viewer as a tool to destroy, to investigate, and to reconstruct. (242)

More specifically, Krauss proposed the idealist assumptions underlying traditional sculptural practice emerge from position and perspective, arguing against the possibility of prior or absolute knowledge.[1] She emphasized how theatrical elements in sculpture could practically disrupt classical conventions that persisted in twentieth-century variants, including futurism, constructivism, and their technological extensions.[2] With the discussion by Krauss, this reconceptualization of theatricality is found in the works of artists like Claes Oldenburg, Robert Morris, and Bruce Nauman. Their practices demonstrated how theatrical elements could serve to investigate fundamental questions about the nature of sculptural objects and our modes of knowing them.

2.2.1. The Phenomenological Turn

Theoretically, the phenomenological perspective illuminates how the artistic practices argument by Krauss transformed the aesthetic object from a self-contained artwork into a catalyst for the embodied spatial experience.[3] The viewing space became an activated field where the observer's bodily presence and movement were essential to the work's completion. This shift represented a fundamental reconceptualization of the artwork's materiality: rather than existing as an autonomous object, the sculpture functioned as a site of perceptual engagement that demanded bodily presence for its full realization.

The apparent paradox of Minimalist sculpture lies in how its extreme emphasis on objecthood ultimately necessitated the viewer's physical presence for its completion, thereby elevating the role of perceptual experience.[4] This transformation marked a decisive shift from the traditional subject-object dichotomy of art appreciation toward a phenomenologically grounded bodily experience.

2.2.2. Institutional Critique by Foster

Hal Foster's subsequent analysis further developed this critique of Friedian modernism. Writing in 1987, Foster identified a fundamental shift in artistic motivation away from Fried's insistence that art must "compel conviction (Fried 1998b, 43–44)." Instead, Foster argued that the innovative art of his generation sought specifically to trouble conviction and demystify belief. This shift marked a crucial transition in artistic practice and critical discourse.

Foster characterized this postmodern impulse by relating it to Marcel Duchamp's original exposure of art's institutional nature. He argued that "quality," once exposed as an imposition of normative standards, had been displaced by "interest" as a criterion for artistic evaluation. This shift fundamentally altered how artistic development was understood: rather than pursuing formal refinement toward pure essence, artists increasingly engaged in structural historical negation, questioning and expanding the received paradigms of artistic practice. As Foster states:

> ...the object of critical investigation becomes less the essence of a medium than "the social effect (function) of a work" in the present, and, perhaps most important, the intent of artistic intervention becomes less to secure a transcendental "conviction" in art and its institutions than to undertake an immanent critique of its rules and regulations. (Foster 1996, 57)

This transformation entailed a shift in critical focus from investigating the essence of artistic media to examining the social function and effect of artwork in its present context. Most significantly, this distinction between formalist-modernist and postmodernist art could be characterized as a movement from "seeking the essential" to "revealing the conditional." (57)

The debates surrounding Minimalism in the 1960s and 1970s highlight a key shift in artistic and critical thought. Fried's critique of theatricality as a threat to object purity was challenged by Krauss and Foster, who saw theatricality as a means to reframe sculpture's relationship to the viewer and to institutional critique. Through artists like Oldenburg, Morris, and Nauman, theatricality became a method for questioning established norms and rethinking the nature of objecthood. These discussions not only redefined sculpture but also paved the way for future explorations of materiality, perception, and social context in contemporary art.

3. Systems Aesthetics and Materiality

The emergence of systems aesthetics in the late 1960s represented more than just another artistic movement; it marked a fundamental epistemological shift in how art engaged with reality. While Fried viewed the theatrical aspects of Minimalism as a departure from modernist autonomy, Jake Burnham recognized these changes as a broader paradigm shift. Burnham's essay "Systems Esthetics" (Burnham 1968b) emerged as a critical response to the minimalist object-based art. He viewed this very theatricality as indicative of a more significant cultural transformation—a shift away from the notion of fixed objects towards an emphasis on relational systems.

The 1960s marked a pivotal transformation in modernist formal aesthetics, characterized by artistic experiments that transcended traditional boundaries of painting and sculpture. During this period, various artistic practices—including Happenings, Minimalism, kinetic art, environmental art, and Art and Technology initiatives—began to emphasize process, event, occurrence, and theatricality over object-based art. This shift coincided with significant developments in the intersection of art and technology.[5]

3.1. Systems Aesthetics, Real-Time Art, and Objects

Burnham's conceptualization of "systems" draws heavily on Ludwig von Bertalanffy's theory of General Systems Theory, (Bertalanffy 2003) which posits that systems are "'complex of components in interaction,' comprised of material, energy, and information in various degrees of organization." (Burnham 1968b, 32) According to Burnham, the term "system" offered the most appropriate lens through which to interpret the emerging practices in contemporary art. He defines a system as a dynamic network of components in interaction, suggesting that the boundaries traditionally associated with art—such as the frame of a painting or the proscenium of a stage—are dissolved in favor of systems that are contingent and ever-changing. This shift towards systems thinking parallels Thomas Kuhn's idea of scientific revolutions,[6] where he describes how scientific paradigms undergo shifts that fundamentally alter the way knowledge is understood (Kuhn 2012).

Burnham argues that this historical moment was pivotal for art.[7] In practical terms, this conceptual shift manifested as a focus on process rather than form. Whereas traditional artworks emphasized fixed shapes and visual metaphors, Burnham's concepts on "systems" suggested that art could be understood as an ongoing, reconfiguring process. The artworks, rather than being fixed, could be seen as

always in a state of reorganization, mirroring natural systems. This move from objecthood to process meant that artworks, instead of being passive objects, became active participants in an ongoing process of change.

One of the key principles of systems thinking, introduced in the 1940s, was the concept of "homeostasis"—the ability of systems to self-regulate and maintain balance through feedback mechanisms (Hayles 1999). These feedback loops were integral not only in biological systems but also in cybernetic systems (Wiener 2019), where the flow of information allowed for the regulation and adaptation of processes. As Burnham integrated these ideas into art, he proposed that contemporary artworks could function as autonomous systems, interacting with their environments in "real time" (Fiske 2016). For instance, in his discussion of artists such as Gianni Colombo, Les Levine, and Hans Haacke, Burnham emphasizes artwork, rather than being a fixed object, became an ever-changing, self-organizing system. This art form operated through continuous variation, defying the static definitions of material or form typically ascribed to Minimalism Art. Haacke's Condensation Cube (1963–1967) (Fig.1.), for example, exemplifies this shift. In this piece, environmental factors like light and temperature continuously change the state of the water within the cube, creating a piece of art that operates autonomously, independent of the viewer's perception or participation. Haacke's work positions the artwork as an open system that evolves over time rather than a static object to be passively consumed.

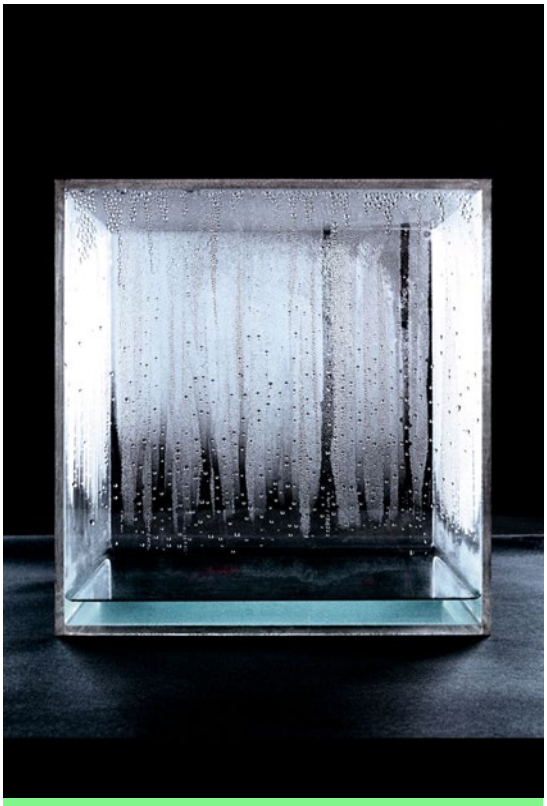


Fig. 1. *Condensation Cube*, Hans Haccke, 1963-67. © Hans Haacke, VEGAP, Barcelona.

By adopting the principles of cybernetics and systems theory, Burnham and these artists transformed the nature of what art could be. The systemic approach practices active processes that reflect the ongoing feedback loops inherent in natural, biological, and technological systems. In this sense, art became a continuous process of variation and transformation, challenging the static definitions of material and form that had previously defined Minimalism.

3.2. Systems Aesthetics and Social and Political Changes

While the concept of Systems Aesthetics emerged as a theoretical shift in art, it is crucial to acknowledge the historical and political forces that shaped its development. At the core of systems theory lies the assumption of technological neutrality; however, this neutrality is difficult to sustain when we consider its origins. Systems theory was not simply a product of academic curiosity but was deeply tied to military needs during World War II.[8]

This militaristic background casts a shadow over the seemingly neutral application of systems theory to art.[9] As Krauss argues, technology is never neutral; it is shaped by the social and economic structures within which it is deployed.[10] She critiques the mechanistic worldview embodied in much of contemporary sculpture, which was often produced in service of such technological and social control mechanisms (Krauss 1981, 221). For Krauss, the aesthetic of technological systems, while compelling, reflects and perpetuates a vision of the world as governed by impersonal forces, a view that much of contemporary art—especially in its postmodern form—actively sought to challenge.

Art movements of the 1960s, particularly conceptual and minimalist art, engaged with technology, yet their practitioners were often wary of its associations with control and coercion. The ideological shift during this period, particularly the countercultural and anti-authoritarian movements, meant that systems—once seen as neutral and objective—came to be viewed as instruments of social and institutional power.

This rejection of technological art practices was also influenced by the growing recognition of the role of social systems in shaping political life. As mentioned by Francis Halsall,

> [...]general social and political changes also raised interest in the notion of systems. Such civil disobedience often directed its anti-establishment and anti-authoritarian rhetoric against the 'system.' Hence systems became associated with institutional power or a prevailing social order. (Halsall 2008, 101)

In art practice, states by Halsall, "this is led to the belief that the social system could be changed by active artistic participation in it," and especially refers to the concept of time of traditional artworks "exist in 'mythical time', that is, in an ideal historical timeframe separated from the day-to-day events of the real world." Some artists, such as Haacke, attempt to "integrate their works in the actual events of the 'real world,' that is the world of politics, money making, ecology and other pursuits (102)."

The relationship between theatrical experience and systemic engagement reveals different conceptualizations of artistic time. Krauss's analysis of theatrical and performance art emphasizes a kind of phenomenological time, focusing on the immediate, embodied experience between viewer and artwork. In contrast, Burnham's concept of "real time" addresses art's engagement with

ongoing social, political, and ecological processes that function independently of human perception. This distinction is exemplified in Haacke's Condensation Cube, where physical processes continue regardless of observation, demonstrating how systemic art operates beyond the confined temporal experience of traditional viewer engagement. The temporal framework in artworks becomes essential in distinguishing between Fried's and Krauss's debate on the notion of "instantaneousness" (ideal time) and "endless duration"—where the theatrical experience creates a suspended duration—and Burnham's "real time," which engages with the actual temporal unfolding of social and ecological systems.

4. Social and Ecological Systems in Artworks of Hans Haacke and Pierre Huyghe

4.1. Systems Aesthetics and Haacke

Aligned with Burnham's "systems aesthetic", Haacke's work emphasizes interconnected systems—biological, ecological, social, or technological—as central to the creation and interpretation of art. This approach foregrounds the relationships and processes within these systems.

However, in critiquing systems aesthetics, depends on an opposition of natural and social, Benjamin H.D. Buchloh argued that Haacke's adoption of Burnham's approach could not escape charges of "techno-scientific reductivism" (Burnham 1968b, 35). In his view, systems aesthetics detaches art from its historical and political roots by positioning it within an ahistorical, rationalist framework. This detachment, according to Buchloh, represses historical memory and displaces art's critical engagement with the sociopolitical contexts in which it operates (Buchloh 2003). Buchloh's critique underscores the danger of systems aesthetics falling into a formalist trap where technology and systems become ends in themselves, detached from the material conditions that shape them.

Central to Buchloh's critique is his insistence on a clear distinction between natural and social systems, a division he argues is ideologically undetermined and immutable. For Buchloh, Haacke's work remains insufficiently political unless it explicitly addresses social systems rather than biological or physical ones. This perspective suggests that Haacke's engagement with systems theory—while innovative in its application of feedback mechanisms and dynamic models to art—does not adequately foreground the political implications of his practice (Buchloh 1995, 49). For instance, his works *MoMA Poll* (1970), *Shapolsky et al. Manhattan Real Estate Holdings,*

a Real-Time Social System, as of May 1, 1971 and *Sol Goldman and Alex DiLorenzo Manhattan Real Estate Holdings, a Real-Time Social System, as of May 1, 1971* engage with the real social context. However, this critique is contested by contemporary thinkers like Bruno Latour, whose work challenges the rigid separation between nature and society. Latour, introduced by Luke Skrebowski, in his advocacy for a "political ecology" (Latour 2004, 231), argues that the natural world is itself politically constructed and deeply intertwined with social systems (Skrebowski 2008, 75). In this view, the binary opposition between nature and society, which Buchloh upholds, needs to be rethinking. Rather than treating the natural world as a neutral backdrop against which social dynamics unfold, Latour proposes that the ecological and social realms are co-constitutive, with each influencing and reshaping the other.

Haacke's practice, then, offers a compelling response to the dichotomy between natural and social systems that has been a longstanding feature of modernist thought. By applying systems theory to both biological and social phenomena, Haacke's work illustrates how the formal and dynamic models of systems theory can be used to understand the overlap and interconnection between these traditionally discrete domains.[11] Haacke's art traces an increasing scale of systemic complexity, from physical and biological systems to social systems, demonstrating how these domains are entangled rather than separate and hierarchical structured in operational systems. This is not just a theoretical intervention but a practical one, as Haacke's artworks refuse to recognize the boundaries that have been established between nature and society. His ecological pieces like *Chickens Hatching* (1969), and *Rhine Water Purification Plant* (1972) (Fig. 2.) merge natural and social elements to critique dominant systems. In doing so, his work pushes against the modernist myth that these realms should remain distinct and untouched by one another, and differentiate with the theatricality practices that emphasize the experience of duration.

Skrebowski importantly argued Haacke's work avoids reducing technology and systems to either purely optimistic or purely dystopian visions, a binary often employed in critiques of technophilia and technophobia (Skrebowski 2008, 58). Rather than embracing or rejecting technology outright, Haacke uses technological resources—such as feedback loops, sensors, and other mechanistic devices—to critically engage with and expose the social and cultural systems that underlie technological applications. His approach refuses to take technology at face value, instead investigating its role in shaping human be-

havior, power dynamics, and ecological relationships. In this way, Haacke's work becomes an active inquiry into how technology and social structures are mutually constitutive, rather than presupposing a separation between the two. His use of systems theory does not function as a neutral, scientific tool but as a method of exposing and critiquing the ideological structures that govern both natural and social systems.

Further states by Skrebowski, this refusal to adhere to the binary division between nature and society is central to Haacke's political engagement. As his works increasingly reflect on the environmental and industrial systems that shape human existence, they also point to the limitations of systems thinking when applied to art without a critical awareness of the power dynamics embedded within those systems. Haacke's work, far from representing a break between a pre-political and post-political phase, is consistently political.

His entire oeuvre reflects a critical stance toward both the systems of art production and the broader societal systems they reflect and uphold. By interrogating systems, whether they are biological, ecological, or social, Haacke's work brings material agency into focus—showing how systems, with their inherent dynamics and feedback loops, can reveal and potentially alter the socio-political realities they inhabit.



Fig. 2. *Rhine Water Purification Plant*, Hans Haacke, 2017. ©Hans Haacke.

4.2. Pierre Huyghe and the Ecological Materialism of Systems

Pierre Huyghe's *After ALife Ahead* (2017) and *UUmwelt* (2018) exemplify a shift in contemporary art toward systems aesthetics grounded in ecological materialism. Huyghe dissolves the viewer's privileged position, integrating them into a dynamic system where human agency is but one variable among many. As Skrebowski notes, this reflects a broader "ecological turn" that collapses the modern divide between nature and society, challenging both Fried's human-centric formalism and Hal Foster's model of institutional critique, which presumes a stable boundary between art and its sociopolitical context (Skrebowski 2019, 67).

In *After ALife Ahead* (Fig. 3.), Huyghe constructs an ecosystem where algorithms, living organisms, and environmental factors interact unpredictably. Flora Katz emphasizes that the essence of *After ALife Ahead* lies in its constant state of change, which is not under the artist's direct control.[12] The artwork signals a shift towards material realism, situating human extinction within the broader narrative of the planet's sixth mass extinction—a phenomenon distinct from previous, naturally occurring extinctions.[13] Katz further states that the

artwork does not adhere to a clear, predictable path but instead allows all elements to change continuously, influenced by their internal properties and the external space they occupy. She suggests the concepts of "randomness/determinacy" (*laisser être/déterminé*) play a crucial role in understanding the work's nature. Interestingly, Katz also argues that in Huyghe's work, the elements are not entirely free to evolve without limits; they are constrained by their inherent material properties, the external space, and the network of interactions set up by the artist (Katz 2019). This interplay between randomness and determinism reveals the intricate complexity of the ecosystem, where change is both driven by random events and structured by the internal logic of the system.

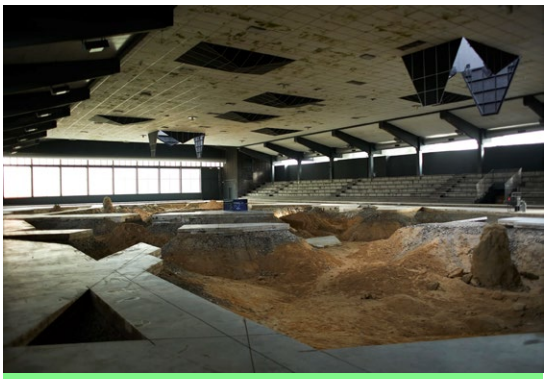


Fig. 3. *After Alife Ahead*, Pierre Huyghe, Installation view, 2017. ©Pierre Huyghe.

In this perspective, the viewer's experience of the duration is different in Haacke's and Huyghe's art. Haacke's control of social and ecosystem focuses on the "real time" which Huyghe here, followed by Katz, the work invites viewers to envision a world beyond destruction, where thoughts of extinction provoke a disconnection from the familiar and forge new connections with the future. This concept could be understood as an emphasis on a critique of historical time that, far from merely critiquing ecological catastrophes, the work challenges viewers to contemplate humanity's role and place within the grander scheme of history. This aligns with Freid's argument of "presentment of endlessness" of the Minimalist and Krauss's critique of prior or absolute knowledge about the object and viewer themselves that is preconceived by viewers in modernist art, but whereas Krauss emphasized the viewer's experience relationship to the work, Huyghe subordinates human experience to the system's emergent agencement (Skrebowski 2019, 72).

Based on his previous practice, in *UUmwelt* (Fig. 4.), Huyghe keeps exploring an ecosystemic approach that prioritizes change, complexity, and relational dynamics. While rooted in his previous works, this evolutionary step achieves new heights in *UUmwelt* through collaboration with Japanese neuroscientists (Shen et al. 2019). Utilizing Artificial Intelligence (AI), this collaboration facilitates transforming human brain activities into visual displays. The exhibition's central feature is large LED walls that exhibit thousands of AI-generated images. These images are uniquely responsive to environmental stimuli, such as changes in light, temperature, and humidity, detected by sensors within the gallery. In addition to its digital components, *UUmwelt* integrates living biological elements.[14] As Huyghe himself reflects, the exhibition does not aim to present a fixed narrative or aesthetic for the viewer but rather seeks to exhibit the viewer within the ev-

er-changing conditions of the work itself. Referenced by Skrebowski, Huyghe describes, "You set conditions, but you cannot define the outcome...there is a set of elements, the way they collide, confront and respond to each other is unpredictable." This idea of "exhibiting someone to something," rather than "exhibiting something to someone," is emblematic of Huyghe's rejection of anthropocentrism and his exploration of the material agency of nonhuman entities within the artwork (Skrebowski 2019, 70).



Fig. 4. *UUmwelt*, Pierre Huyghe, Installation view, 2018. ©Pierre Huyghe.

Skrebowski frames Huyghe's art as a rejection of the "modern constitution": the work's refusal to separate natural and social sciences. He states as,

> Rather, Huyghe's work can be more productively understood to participate (as indeed does Latour's own more recent work) in a general ecological turn in the humanities that is consequent on the refusal of the (modern) separation between the Naturwissenschaften and the Geisteswissenschaften (and for which work undertaken in Medienwissenschaft is an essential reference point). (72-73)

In this context, it seems that a kind of ecology materialism is central to Huyghe's practice, which emphasizes the material agency in the systemic art approach. Huyghe's works are not just a representation of life, matter, and machine, nor a mere critique of ecological issues, but a material engagement with the forces of change, emergence, and transformation. It challenges viewers to reconsider the place of human agency within the broader ecological and systemic networks on Earth. Skrebowski further connects Guattari's notion of a "new aesthetic paradigm" to broader ecological thinking. It contrasts this new paradigm with modern aesthetic practices, which are often institutionalized, and draws from more fluid, pre-modern societies (78). By weaving together concepts of randomness, determinism, and material agency, Huyghe offers a speculative view of the world that transcends traditional artistic forms and invites a more complex understanding of the relationships between art, nature, and technology.

In examining the works of Hans Haacke and Pierre Huyghe, this section explores the dynamics of systems and the material agency inherent in their interactions. Both artists embrace a complex, interconnected view of the world, where boundaries between the natural, social, and technological are dissolved, giving rise to artworks that are as much about process and transformation as they are about fixed forms. Haacke's art demonstrates the potential of systemic practices

to reveal the forces that shape our social and political realities. His application of systems theory—whether through biological processes, social structures, or technological networks—illuminates the ways in which power and control are embedded in the very systems that govern our lives.

Similarly, Huyghe's ambitious project *After ALife Ahead* and *UUmwelt* push the boundaries of artistic practice by embracing ecological complexity and material agency. Huyghe's works are dynamic systems in constant flux, where the interactions between living organisms, technology, and environmental factors produce unpredictable and emergent outcomes.

Importantly, the artworks of Hans Haacke and Pierre Huyghe introduce a "duration" that challenges the static time frameworks proposed by Michael Fried and Rosalind Krauss. Fried emphasizes the viewer's perception of instantaneousness, critiquing Minimalism for disrupting the autonomy of the artwork by involving the viewer. Krauss extends this critique, suggesting that time in artworks is governed by resistance to the viewer's temporal passage.

In contrast, Haacke and Huyghe create systems where time is not fixed or measured but unfolds "real" and unpredictably through interactions within the artwork. For Haacke, works like *Chickens Hatching* (1969), and *Rhine Water Purification Plant* (1972) emphasize time as a "real time" process driven by environmental feedback rather than viewer participation. Similarly, in *After ALife Ahead* (2017) and *UUmwelt* (2018), Huyghe's work intertwines time with the cycles of living organisms, AI, and environmental factors, where the system evolves through continuous change. In these works, time and material agency are inseparable. Time is not a static, self-contained moment but an ongoing, relational process, emerging through the interdependent functioning of biological, technological, and environmental systems. The presentness in these artworks is an evolving transformation, shaped by the agency of the materials and systems themselves.

5. Material Agency in Systems

This final section builds upon the previous discussions of theatricality, objecthood, and system aesthetics to analyze the perceptual experiences within different artistic contexts and the internal relationships of the artworks. It further explores the implications of material agency within these systems, especially from the perspective of the expanding technological systems in contemporary practice and complex ecologies. The discussion emphasizes how artistic practic-

es, particularly those engaged with system aesthetics, contribute to a broader material thinking that challenges traditional notions of objectivity, which relate to the nonhuman turn in thinking.

The exploration of material agency in art has long involved the relationship between natural objects, mechanical objects (machines), and humans. One way to consider this relationship is through the framework of "Quasi-Objects", a concept quoted by Halsall, a term Latour adopts from Michel Serres to describe entities that emerge from the interplay between human and nonhuman activities (Halsall 2016, 449-450). Quasi-objects emerge from the interplay between human and nonhuman elements, where identity and function are not inherent but relational. They exist as "strange new hybrids" between things and situations, acquiring meaning only within specific contexts or relational networks. This understanding of material agency challenges the idea of fixed identities, particularly within system aesthetics. Latour's flat ontology extends this argument, suggesting that all entities—whether social, cultural, or physical—are part of a network of relations and do not occupy a privileged ontological position. This relational understanding positions objects and systems as part of an interconnected whole, rejecting the traditional hierarchical view where human perception holds a dominant position over nonhuman entities (451).

This material consideration of art practices raises philosophical reflections about the position of the human subject in relation to technological systems and complex ecologies. In particular, the integration of natural and social systems in technological systems necessitates a reflection on the limitations and constructions inherent in human perception. Burnham's reflections on the cognitive dimensions of art underscore this point, particularly his assertion that art, like technology, is deceptive in that it "holds out the possibility of human transcendence," aimed at overcoming natural forces. However, Burnham cautions that both art and technology ultimately expose the illusion of transcendence, revealing that humans are governed by their "perceptual illusions" rather than possessing absolute control over their environments (Burnham 1983, 211). Burnham's critique intersects directly with the core issue of system aesthetics: the tendency to overlook the constructed nature and limitations of the observer's perspective. Whether observing biological, human-machine, artistic, or social systems, the act of observation itself can foster a false sense of objectivity. This detached, mechanistic view fails to account for the interconnectedness of systems, leading to a disconnection between the information observed and the entities that ob-

serving. Burnham's critique also resonates with Krauss's argument presented earlier in this article. Krauss states that when observing an object, "one to think of oneself as capable of reconstituting the object, from all around itself, regardless of one's own position, or its, is a notion that wants to forget that meaning arises only from *this* position, and *this* perspective" (Krauss 1981, 240). The parallel critiques of "perceptual illusion" and "reconstituting the object" both highlight how relations between humans and objects within spaces or environments are inherently complex, with no singular viewpoint capable of capturing these relations comprehensively. More importantly, the positional and spatial relations must be analyzed dynamically, particularly in complex systems, to reveal the agency of materials that are technically and ecologically connected from nonhuman perspectives.

Beyond the positional relations between observers and objects, the challenge to traditional notions of time is central to contemporary practices that engage with system aesthetics. Artists like Haacke and Huyghe highlight their practices as a dynamic, evolving process rather than a static framework. Haacke's works illustrate how time in art is driven by "real time" processes. Huyghe's more recent works further intertwine time with biological cycles, AI, and environmental systems, creating works that evolve continuously. In these works, time and material agency are inseparable, as the evolving transformation of the artwork is driven by the agency of the materials and systems themselves. This shift in understanding challenges traditional concepts of artistic temporality. While conventional frameworks often position time as fixed or measured against human perception, Haacke's and Huyghe's works emphasize time as relational and contingent upon the interactions between biological, technological, and environmental components. These works reveal a re-conception of "presentness" that is not a fixed moment but a variation and ongoing, evolving process shaped by the material agency of the systems involved.

The discussion of the relation of human and nonhuman and the time frame in ecological and technical systems leads to the consideration of material agency, raising critical questions about the role of nonhuman perspective in contemporary art history. Specifically, materiality critiques traditional human-centered viewpoints when examined through ecological and technical systems. It challenges the idea of an objective, stable viewpoint that can be detached from the static relations being observed. Material agency in artistic practices thus offers a form of critique that extends beyond representation, presenting a counterpoint to the idealized notions of objectivity that

have dominated Western thought. This critique aligns with the notion of "agential realism" (Barad 2003, 824), which posits that reality is constituted through the interactions of various agents—human and nonhuman—and that these interactions cannot be understood through the detached observation of isolated systems. In "Agential Realism," Barad proposes that reality's fundamental units are not static objects but "phenomena" emerging from specific "intra-actions" (822). This framework replaces the concept of independent entities acting upon each other with a model of co-constitution through entanglement. The agency of materials in art helps reveal the complex, entangled realities that emerge from these interactions. Through analyses of position, relation, and temporality based on system aesthetics and objecthood, this article tries to offer a more interconnected and ecological view of reality where humans, matter, and machines are systemically entangled both in historical art contexts and contemporary practice.

Notes

1. She critiqued the notion of "axiomatic coordinates" that presumed the possibility of comprehending an object in its totality, independent of the viewer's position. As she noted, "The meaning of depth is nowhere to be found in this suspension." This critique targeted the modernist presumption that artwork could achieve a kind of transcendental presence, existing independently of temporal and spatial contingencies.

2. By the mid-1960s, she argued, theatricality and performance had created an "operational divide" between the sculptural object and preconceived notions about knowledge that viewers might hold about both the object and themselves (Krauss 1981, 240).

3. The movement's development in the 1960s was significantly influenced by Maurice Merleau-Ponty's phenomenology of perception, marking what some scholars have termed a "phenomenological turn" in sculpture. Merleau-Ponty's assertion that bodily engagement forms the foundation of human perception offered a theoretical framework that helped explain the experiential nature of Minimalist works. According to his philosophy, visual perception cannot be separated from bodily existence; kinesthetic and tactile experiences are inherently embedded in the act of seeing. This understanding suggests that comprehension of an object's essence requires physical engagement through movement and touch (Merleau-Ponty 2002).

4. As Claire Bishop notes in "Installation Art: A Critical History," sculpture in this context transcended its traditional status as a closed form, becoming instead a perceptual field requiring the viewer's bodily presence (Bishop 2006).

5. In 1966, Robert Rauschenberg collaborated with Robert Whitman, Fred Waldhauer, and Billy Klüver from Bell Laboratories to establish Experiments in Art and Technology (E.A.T.), culminating in the technological art performance "9 Evenings: Theatre and Engineering" at the New York Armory. This technological turn in artistic practice was further institutionalized through exhibitions such as "The Machine as Seen at the End of the Mechanical Age" at the Museum of Modern Art and "Cybernetic Serendipity" at the Institute of Contemporary Arts, London, both in 1968. As seen in Edward Shanken's "Art in the Information Age: Technology and Conceptual Art" (Shanken 2002).

6. For Burnham, the transition in art practices mirrored the transition in science: the move from classical physics to atomic theory at the turn of the 20th century, which began to decenter the concept of matter and emphasize relational processes.

7. He draws on the scientific advances of the early 20th century, such as Planck's quantum theory and Einstein's theory of relativity, which revealed that material reality, whether biological or non-biological, could be understood as a series of interconnected energy states rather than as fixed, static entities. The implications for art were profound: artists could no longer be content with creating works that merely mimicked the tangible world; instead, they could create works that embodied systems of interaction—systems that, like the physical world itself, were in constant flux (Burnham 1968a, 113).

8. The principles of cybernetics, for example, were initially developed to address complex control systems, such as the tracking mechanisms for anti-aircraft guns. Norbert Wiener's application of feedback loops to automatic control systems, leading to the invention of the air defense warning system, epitomizes the fusion of military technology and systems thinking that set the stage for later developments in cybernetics and systems theory.

9. The post-World War II era saw an increased awareness of the ways in which technology, military-industrial complexes, and capitalist systems were intertwined. The global upheavals of the 1960s, particularly the May 1968 protests in France, the Vietnam War, and growing environmental concerns, led to widespread skepticism about the role of technology in modern life. Artists, philosophers, and political theorists began to question the implications of technology in a world increasingly dominated by surveillance, control, and mechanization. Burnham's systems theory, with its roots in the military-industrial complex, faced substantial ideological resistance in this climate. In particular, the critique of "technological determinism" became a central theme in art and political discourse.

10. She mentioned, "But many liberal and Marxist historians and social philosophers have labored to show us that these technocratic goals are not value-free but are products of a social and economic system for which 'control' of that kind is the logical corollary. Burnham's book is one of the most extensively and closely argued presentations of sculpture made in the service of a mechanistic view of the world. But that view — far from being necessary — is precisely what much of contemporary sculpture (and art in general) wishes to overturn." (Krauss 1981, 221)

11. Introduced by Skrebowski, As William Rasch and Cary Wolfe have noted, systems theory applies the same set of formal models to both organic (biological) and mechanical (technological) systems, thus challenging the ideological divide between what is considered natural and what is deemed social (Rasch and Wolfe 2000, 17).

12. As Katz points out, the second key dimension of Huyghe's system is its continuous change, which makes the outcomes of the system unpredictable. The work's unfolding trajectory, like that of a complex system, is open and characterized by uncertainty—traits that are central to the system's potential for entropy. In *After ALife Ahead*, some elements, like the flight paths of bees, exhibit discernible patterns, while others, like the behavior of cancer cells, are entirely unpredictable. These interactions introduce an element of randomness within the system, producing outcomes that persist until the next change occurs.

13. Katz states that the artist situating human extinction within Earth's sixth mass extinction, the work destabilizes anthropocentric narratives, rendering viewers incidental to a system that operates independently of their perception (Katz 2019).

14. Emphasized by Skrebowski, a notable inclusion is a community of blue bottle flies, which experience their entire life cycle within the exhibition space. Accompanying these biological elements are various environmental prompts — visual, auditory, and olfactory — as well as distinct computer-generated sounds. Huyghe's deliberate decision to leave layers of paint and dust on the gallery wall's surfaces allows for their natural displacement and alteration throughout the exhibition, further contributing to its dynamic ecosystemic ambiance. (Skrebowski 2019)

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Apollo e Marsia: Time and Memory under Tension

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This paper describes a hybrid installation - *Apollo e Marsia*, based on a painting by Tintoretto - incorporating music performance on video, physical instruments and machine listening. It explores the dynamics of musical memory, particularly directly after performance and under stress. Through the use of physical instruments and machine listening, it proposes to situate the listener/viewer directly in the environment of the work. Video is shown to be an integral part of contemporary engagement with art music. The work serves as an example to reexamine the status of music as a temporal object and the nature of Stiegler's "tertiary retention", and suggests an alternative way to engage with the arts of time.

1. Source

In 1545, the satirist and blackmailer Pietro Aretino received two paintings from Tintoretto, for the ceiling of his bedroom in Venice. One of these represents a story from Ovid: the musical contest between the god Apollo and the satyr Marsyas, who had challenged the god to a contest ("*The Contest between Apollo and Marsyas*," Wadsworth Atheneum, Hartford Connecticut) (Fig. 1). From Ovid we know the gruesome end that is to befall Marsyas: he must inevitably lose the contest and will be flayed alive (Ovid 1986). But Tintoretto depicts the moment when they have both just finished playing, before judgement is passed; Apollo holds a viola da braccio with a clearly visible sympathetic string, Marsyas a long woodwind instrument. In mid-gesture, they both appear to have just played their last note. Midas is consulting with his fellow jurors, accompanied by a glamorous female assistant (game show formats have a long history). Painting – this painting – does not work like a photograph; there is no punctum here. Time is both compressed and expanded; the painting holds us suspended, dizzy, between its immediate past and its immediate future.

For the two competitors, this is above all a moment of memory – an expanded, stretched moment, because they cannot know when the judgement will arrive. Except in the most unengaged of circumstances, musical time is not experienced in minutes and seconds. In the general case (favourite karaoke songs excluded) the memory of

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musical experience is not the replaying of a soundfile from start to finish. Intermodulating patterns of form, salience or reference are further complicated by the differential dynamics of the various cognitive mechanisms that constitute musical memory. The resonance of stress makes the immediate memory of personal performance yet more complex, and in the highly-charged moment depicted here, still more so. Each musician is trying to remember, to assess their own performance. In addition, each is also trying to recall that of the other, and to reckon their relative advantages or weaknesses. The moment depicted is of a particularly binary nature (live/die), but the general situation is familiar to any performer. The painting is thus highly suggestive of an intense behaviour of musical memory, in which two sets of actions will inform each other increasingly with their constant re-imagining. It also presents a situation, an emotional state, acutely resonant to any experienced performer.



Fig. 1. *The Contest of Apollo and Marsyas (detail), Wadsworth Atheneum, Hartford, Connecticut*

2. Work

In its complete form, *Apollo e Marsia* is a hybrid installation consisting of two 85-inch UHD LED screens, positioned opposite each other at a distance of 4 meters, four computers, two sound systems and two physical instruments. One screen displays a filmed performance by a musician playing a viola d'amore (a seven-stringed bowed instrument with seven further sympathetic strings below the bridge), the other playing an alto flute - performances of roughly 23 and 25 minutes respectively (Figures 2 and 3). Each screen is surrounded by a pair of loudspeakers mounted at ear level, a microphone above the screen and a physical instrument. The sound is played in 5.1 format. The ear-level speakers present the instrumental sound untreated. Two channels of processed instrumental sound are played through the physical instruments: that of the viola d'amore through a pair of long transparent acrylic tubes, that of the alto flute through an instrument, likewise transparent, with two 3-meter strings. The processed memory of each performer is thus acoustically modulated by the means of sonic production of the other. Sound from the tubes is transmitted through a loudspeaker built into the base of each. The strings are excited by audio signals transmitted through the *body* of two 48v motors. A mac mini behind each instrument handles the video and soundfiles. A second computer on each side runs a k-nearest neighbour engine, listening to the whole through the microphone, responding on the basis of its impressions accumulated through each 24-hour period, and sending its output through the physical instru-

ments. The fifth audio channel of each 5.1 file serves as a constantly varying control to this simple AI, determining the level of its listening.

The listener/viewer is situated between the two protagonists. Their choice of orientation is probably most influenced by the degree of activity in either performance, or perhaps the strangeness, the unattributability of certain sounds from the physical instruments (Fig. 4). However closely their listening is focused on a single source, they will hear all the strands of sound simultaneously: the treated and untreated sounds of recorded performances, and the constant dialogues between the two musicians and between present and past. Duration of attention is clearly beyond the artist's control in an exhibition context, and as such too often ignored in sound art. Here the structure of the two recorded instrumental compositions – each consisting effectively of four or five 3' - 8' movements separated by sonic interludes to still images of the instrument alone – provides the clearest background temporal architecture, but in a constantly changing phase relationship.

3. Challenge

The work seeks to explore under temporal magnification what in experience would be a highly time-compressed, stressful, evaluative memory behaviour. A musician's mind would be scanning their memory in a highly nonlinear and unconsciously-directed manner, jumping between moments of positive and negative salience from both performers, quasi-arbitrarily fixating on certain phenomena, exaggerating or ignoring others, and the whole time attempting to construct some informal, n-dimensional score.

At the same time, *Apollo e Marsia* searches for an alternative path to any inherited live-recorded binary in the apprehension of performed music. Video, we should note, is an increasingly common way to engage with art music performance, to the extent that a) musicians feel obliged to add a video component to their output, however static, live or online, to encourage engagement, and b) audiences will studiously watch almost any video feed in a live situation, such that it becomes a conventional skeletal throughline for much experimental music. Stiegler points to the functional role of such passive engagement in the case of cinema (Stiegler 2010, 10). Rather, video might better be considered not as a substitute or a support, but rather as a vital entry point for engagement with music. Banal as this observation may seem, it has significant implications for how we treat such material. The video performance ceases to function primarily by reference; there is no time or place other than the present of the viewer, except for the mythical.

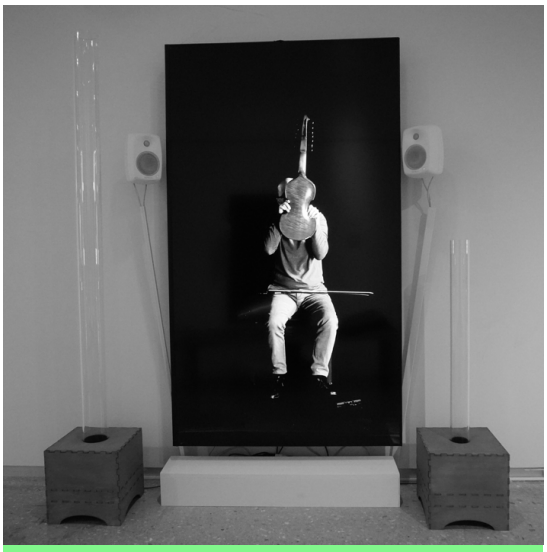


Fig. 2. *Apollo (Marco Fusi, viola d'amore)*



Fig. 3. *Marsia (Richard Craig, alto flute)*

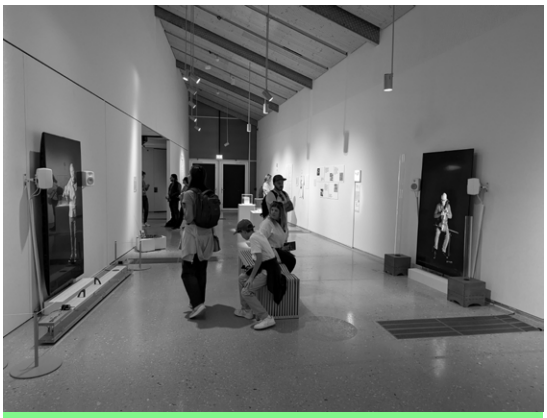


Fig. 4. *Apollo e Marsia in situ (Exhibition Musica ex Machina, EPFL Pavilions, Lausanne, September 2024)*

In the absence of familiar musical form (song, dance, or the norms of the nineteenth century, for example), video affords a thread of linearity that frees the extraordinary range, modality and polyphony of real-time musical memory to do its work. Filmed performance is thus central to the attempt of *Apollo e Marsia* to explore such phenomena, and the ways in which they interact with the ambiguities of liveness and presence.

4. Representation and the dynamics of memory

The viewer/listener is confronted with multiple layers of work: 'work' both in the nominative sense – as constructs with their own mode of production, form and identity – and as layers of different kinds of manipulation. In *Apollo e Marsia* as experienced these are folded together inextricably – from Ovid and Tintoretto to the AI-mediated sounds of the exhibition and its viewers – and yet patterns and resonances across these layers emerge from their interaction.

At the heart of each of the two filmed compositions lies historical material – material to which the filmed performers themselves only have indirect access, through the mediated, transformed, compressed and stressed memory of their own elaborations of sources which were never stated directly in the moment of performance. Two hymns to Apollo inscribed on stone were found at a temple in Delphi: *Paean of Athenaios* and *Paean of Limenios* (Pöhlman and West 2001, 62-85). The pitch indications accompanying the texts are widely regarded as the earliest instances of Western music notation. They themselves can be seen as records, as encodings of hymns sung at games, rather than prescriptive instructions in the sense of a modern score. The surface itself is distressed and fragmented, such that marks are lost. And the process of decoding, beginning with Reinach (1893), still leaves ambiguities – artefacts of cultural memory.

Rather than decoding, the successive re-inscriptions and re-foldings of this material might be seen as moments of transduction. The source material and its various subsequent manifestations do not embody or transmit any kind of message. They are treated as patterns of energy, revealing new aspects of their internal dynamics as they are brought into spaces of increasing dimensionality. The first such transformation happens in the symbolic space of MIDI representation of the ancient source material, then becoming LISP data for manipulation in the computer-assisted composition environment *OpenMusic* (https://forum.ircam.fr/projects/detail/openmusic/), the initial stage in the production of scores for the instrumentalists. Time, sound, memory and movement are all represented as curves

in this environment, rescaled and shifted to produce micro- and macro-wave phenomena as they modulate each other. Wave behaviour and phenomena emerged as central structuring paradigms in working across the multiple modes of representation required by the different environments of generation, manipulation, processing and construction (Viola 2013). Embodied memory plays a part, as the hand and finger movements of each player and the string-crossing patterns of the violist are encoded in the same context.

The relationship between layers of memory (echoic, short- and long-term) and musical form has been studied in detail (Snyder 2016), and fundamental play of memory and anticipation in musical listening is well established (Huron 2008). Such studies relate largely to sequential attention to music that is 'well-formed', not to the multi-directional, fragmented surface of post-performance recall. They do however point to the inextricability of memory and forward-directed imagination. Indeed, research suggests that these are essentially the same mechanism (Budson et al. 2022). Under normal conditions, the principal components of recall of sequential information are well rehearsed: recency, primacy, contiguity, associative asymmetry and semantic proximity (Kahana and Miller 2013). These are in any event nonlinear, subject to progressive unbalancing of focus and increasingly informed by external associations. In situations of stress, such phenomena are strongly further modulated by feedback loops – loops that can themselves proliferate – leading to new artefacts that play no part in the 'original' experience (Tomé et al. 2024). The likelihood of such artefacts diminishes with temporal distance from the stress-inflected moment; more distant recall is clearer about distinction, context and sequence.

In this state of non-intentional self-evaluation, obsessive re-rehearsing of passages is modulated by a polyphonic recall of the performances of both musicians, on time-scales ranging from the complete performance to individual gestures. This material, encoded as waveforms, produces both progressive transformation and sudden switches of state. Passages of sonic and physical memory dissociate and recombine; emergent artefacts become part of the aggregate resource. There is a continuity between this human-directed compositional process and the machine learning by which it will be further mediated; in both cases, a searching for coherence and development is continuously redirected by the emergence of a rhyme or analogy. Machine listening becomes a mode of compression that in its overview and arbitrary access allows the generation of coherent but surprising new material.
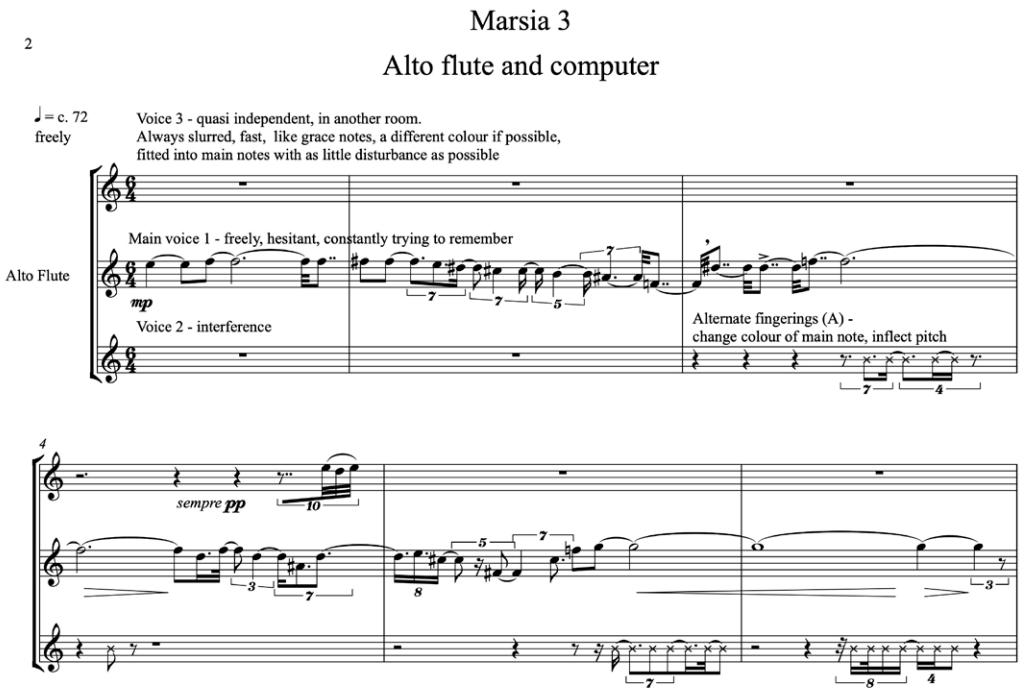


Fig. 5. Marsia, section 3 of score.

In a typical passage, hand movements from one area of performance drive the redistribution of certain pitch elements from another, modulating the shape of an obsessively recalled phrase that links associatively across the source material, the amplitude or resonance envelope of the whole shaped by an insistent central line and interrupted by passing, ungraspable attempts to take the attention elsewhere, to an emerging, unformed memory more remote still. Analogous processes inform the editing of the material this generated as it is re-encoded as Music XML to be manipulated anew in Sibelius notation software. Sometimes this polyphony is assimilated into a single line for the performer; elsewhere the assimilation of these elements in performance itself becomes another layer of 'work'. In some instances, they are presented with multiple staves of notation representing different modes of memory – degrees of certainty, intrusiveness or inaccessibility (Fig. 5).

The recorded performances are then subject to analogous processes of folding, filtering, nonlinear recall and emergent false memory to produce the audio tracks played through the physical instrument accompanying each screen. These are implemented in *Max* (https://cycling74.com), now using a further level of data derived from audio analysis in combination with the symbolic and wave-form material from the initial stage. These polyphonic memory traces are filtered and heard through the means of sound production of the opponent (flute through strings, viola through tubes), while their own sound emerges directly through loudspeakers.

5. Physicality

Each player's memory of their own performance – their sound, invention or virtuosity – is mediated by their attempt to remember and evaluate the performance of the other. While the direct ('live') instrumental sounds are heard from speakers either side of each screen, the sonic memories of player – both Max-processed instrumental sound and AI generated output – are modulated through a physical instrument that represents their opponent. In both cases, sound emerges from a void, a transparent empty space.

Those of the alto flute are heard through two braided steel strings each 3 metres long, mounted on a rectangular cuboid soundbox with transparent acrylic sides, a massive wooden base and a 3mm Alaskan spruce soundboard (kindly supplied by our industrial partner, Chris Maene Pianos). A central laser-cut rose is copied from that of an Egyptian *Ud*. The strings are connected at each end with steel turnbuckles, allowing tuning under tension, and to the soundboard by means of asymmetrical bridges. Modelled after the bridge of the mediaeval tromba marina, the leg not under direct pressure from the string is free to drum against the soundboard at resonant frequencies. After much experimentation with exciters (loudspeaker drivers redesigned to operate in direct context with resonant bodies) it became clear that driving the strings in this way to an appropriate sound level led to unacceptable distortion. Following further work with motors, with different textures on the shaft, it transpired that the motor body itself provided the cleanest transmission across the frequency range. Each string is driven by a single motor, which receives one of the processed 5.1 audio channels. The tuning of the strings derived from *Paean of Limenios*, the flautist's source material.

The analogous sounds of the viola d'amore are heard through two clear acrylic tubes, mounted vertically above loudspeakers – a sort of memory organ. Their lengths – 1940 and 1040 mm respectively – reflect the pitch centres of the Apollonian hymn which forms the basis of the viola's music, *Paean of Athenaois*. The tube diameters follow the practice of *Normalmensur* organ pipe scaling, to encourage appropriate resonance (Mainstone 1998).

6. Obsessive listening

The shifting presence of listeners becomes part of their own experience. The microphone above each screen feeds a second machine. Each side of the installation listens to the room from its own perspective, hearing its own instrument-processed output, that of its opponent, and movement and conversation in the exhibition space.

On each side, a Python machine listening engine then responds, exhibiting a similar set of memory phenomena but now brought into the common present. Incoming audio is sliced using flucoma's 'novelty' analysis (https://www.flucoma.org), and slices are processed by a k-nearest neighbour engine to build a dynamical model of mfcc (spectral) and pitch dimensions. Incoming audio is also matched to the accumulated latent space, according to variable values of temporal distance, probability of prediction, and continuity. The audio is handled using the *librosa* and *pyaudio* libraries. The listening sensitivity of each of the AIs varies continuously and is controlled by the fifth audio channel of the respective performance video. The systems reboot every twenty-four hours, to avoid a terminal accumulation of data, but within that time period the two musicians are listening to themselves, each other and the surrounding environment. The two aural perspectives create two different memories of events, each with their own dynamics and internal associations. The difference in duration between the two video loops avoids precise coincidences and prediction confirmation. Each engine outputs its responses through its respective physical instrument; the constantly reforming memory of each musician is filtered through the sound of the other – haunted by its ghost.

7. Temporal object or constellation?

In developing his notion of tertiary retention, Bernard Stiegler discusses cinematic time, to observe a fundamental relationship between the time of music and that of the moving image; he expends more words on music than on image. His starting point is Husserl's notion of a "temporal object", which Stiegler describes thus:

> [...] a properly temporal object is not simply "in time": it is formed temporally, woven in threads of time – as what appears in passing, what happens, what manifests itself in disappearing, as flux disappearing even as it appears. And the properly temporal object is the ideal object constituting the temporal fabric of the stream of consciousness itself, since the flux of the temporal object precisely coincides with the stream of consciousness of which it is the object. To account for the structure of the temporal object's flux is to account for the structure of the stream of consciousness of which it is the object. (Stiegler 2010, 14)

Husserl's paradigmatic case is melody. In his exegesis, Stiegler expands on that case to propose an interesting distinction between music and sound or noise. He focusses on the note – an apparently

modest concept of extraordinary plasticity: a sound, a frequency, a representation, an instruction. The role of melody here opens up important questions regarding the nature of tertiary retention and its relationship with the temporal object. Stiegler appears to continue Husserl's implicit assumption that a melody is a well-formed construct, amenable to apprehension in its entirety as a unitary object. This may be the case for the simplest song-forms – indeed, that is their strength. But the story of historical western art music could be seen precisely as a search for ways to play with, expand or subvert that possibility. In this respect, Stiegler's tertiary retention may be culturally valid but personally insufficient – that is, art music uses the distancing of inscription and mediation to afford modes of retention beyond the tertiary. Alva Noë's dance-choreography distinction has resonance here art as a human organisational and re-organisational practice – except that music has a deep technicity that right down to its simplest forms engages the most affective strands of human non-referential sense-making (Noë 2015, 13-18).

As common norms of reception have dissolved, modes of engagement with temporal objects have evolved; we begin to study our individual response. *Apollo e Marsia* is an attempt to acknowledge this in the construction and presentation of the work itself, to fold inscription and retrieval, compression and generation into a continuous process. The emergent surface, however, rather approaches a shifting constellation of Deleuze's cinematic "crystals of time" in their third state, a constellation the origins of which are known only through their traces:

> The crystal caught in its formation and growth, related to the 'seeds' which make it up. In fact there is never a completed crystal; each crystal is infinite by right, in the process of being made, and is made with a seed which incorporates the environment and forces it to crystallize. (Deleuze 2013, 92)

8. Conclusions

As they change their own stance and gaze relative to the image, the viewer/listener can engage in slower, more intimate study of the performer, of their features and movement, than is ever possible in live performance. The attempt here is to draw the listener in to search for figure, to dynamically infer process, to build their own space of potential. As we reflect on the condition of music in general, from the perspective of our own technologically-informed moment, perhaps this reminds us that the musical work has always been a virtual entity,

never fixed; in its acoustic surface there is no original. We co-reconstruct and co-imagine in our personal version of a present. Likewise here: the work as perceived consists of layers of mediated objects dynamically producing trajectories between each other. This process proposes a re-articulation of the relationship between video, sound, performance and presence. And it suggests a way of engaging with music in general: as matrix of memories across different time-scales, internal and external to the present performance; as the product of an untraceable pattern of nested, folded inscriptions and reencodings.

The full installation requires considerable resources to be mounted. At its heart, however, are the scores for viola d'amore and alto flute – four movements in both cases, each of which passes through the original material (a structural ghost, never heard in its simple form) with a different polyphony of layers of memory. These items (*Apollo 1-4, Marsia 1-4*) have been prepared for separate performance in the form of a score + Max patch.

Acknowledgements. A vital lesson of this project has been the importance of teamwork, of the role of distributed creativity in the production of such technologically hybrid work. Heartfelt thanks are due to Richard Craig (alto flute) and Marco Fusi (viola d'amore), Shivadas De Schrijver (videographer), Juan Parra Cancino (sound engineer), Magno Caliman and Elisabeth Damai Salverda (instrument builders) and Leonardo Impett (coding).

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Imagining and Inventing Bespoke Devices for Experimental Sound Practices

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This paper looks at the case of do-it-yourself (DIY) musical instruments, and how the somewhat common practice–in certain fields of experimental music at least–of developing bespoke sound devices can present itself as a problem case in light of the role of free activity and the crafting/discovering of prosthetic mediators, as presented by Gilbert Simondon in his book *Imagination and Invention*.

1. Feedback between different regimes

In a 1965-1966 series of lectures for the Institute of Psychology at the Sorbonne University, philosopher Gilbert Simondon presented the course *Imagination et Invention*, later compiled as a book in French, and translated in 2022 to English as *Imagination and Invention* (IMIN) by Joe Hughes and Christophe Wall-Romana. In these lectures, Simondon set out to present and formalise a theory of what he would name the "genesis of images" (5), where he elaborates on a mode of world-being comprised of phases of "anticipation, experience, and systematization" (19) which leads to, and creates the conditions for, the main topic and concern of his course: the act of invention as it relates to mental images. Not so much concerned with how individuals come into being i.e., matters of individuation and ontogenesis, central to his previous work up until that point, in IMIN his energy is directed at how the *transformation of a system* takes place as it is surveyed, experienced, inhabited–until ultimately saturated–by individuals.

Invention is set-up by Simondon, preliminarily, as a consequence of a need for problem solving, an "interruption due to an obstacle" (139). Some ongoing process is brought to a halt demanding thus a reconfiguration of the environment, along with one's interaction with it, in order to permit the process to continue. A rolling boulder blocking a narrow path is suggested; too heavy for the single traveler, but possible to be moved by the collective effort of several travelers. At that point, we can understand that invention is suggested to be predicated on (at least some level of) a formed image of a future goal. This is central, as the dialectics between a current material reality and a subsequent projected state of things will become an operational framework through which Simondon will develop his propositions. The blocking boulder itself fosters the *image* of the beyond-boulder.

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A path to an envisioned result, when faced with a discontinuity imposed by a barrier, sets up a dynamic of feedback between what Simondon understands as two "regimes", or "orders of magnitude": that of the "reality of the result", and that of the "means and subsets within a mode of compatibility" (166), in other words, an interplay between what could be considered the material *reality* of a present moment, and a projected ideal *potentiality* of an envisioned goal. Invention then appears as an emergent property of the communication between those two regimes, a result of the back-and-forth movement along modalities of coupling between organism and milieu, while pursuing a possible barrier-removing solution. Anthropologist Tim Ingold, in his book *Being Alive - Essays on Movement, Knowledge and Description* (2021), will comment on a similar existing feedback loop between ideal images and the material realities which may foster their subsequent realisation, in what he calls "Karl Marx's dilemma":

> [...] the human labour process, said Marx, "ends in the creation of something which, when the process began, already existed [...] in an ideal form" (Marx [1867]1930, 170). Yet for Marx, this model of creation presented something of a dilemma. *For if the form of a thing must already exist in the imagination before the work of production can even begin, where does this initial image come from?* (5, emphasis added)

Once more, a movement between two Simondonian "regimes" is presented, now with special emphasis placed on their co-relation and mutual influence insofar as *production* is concerned: is a crafted object a form of ideal thought that becomes materialised? Conversely, can mental images spawn from *finalised* material objects turned into symbolic representation? In particular, Ingold's concern is one of the relationships, and close circuit, between the regimes of "*consumption* and production, the one converting pre-existing images into final objects, the other converting objects into images" (5). He sets out to emphasize how, problematically to Marx' materialist proposition, "Marx had to pull objects from a hat in order to set the ball rolling" and "to ask which comes first, production or consumption, is to pose a chicken and egg question" (5). In a more general sense though, and more fitting to the purpose of this paper, what is being put forth is a problematisation of *ex nihilo* creation. Ingold's proposition of a close circuit between emergent images and produced objects seems to advocate against a pure from-idea-to-product creation process, where an uninterrupted, unimpeded downstream –which springs from free imagination– would flow in

the direction of a "thing". Finally, if invention is to be understood as triggered by the confrontation of certain organisms with "a discontinuity acting as a barrier to an operative implementation [*accomplissement opératoire*]" (Simondon [1965-66]2022, 139), Simondon and Ingold will then meet while advocating for an understanding that ideas find their origin in some form of perceptual-motor interaction, which is grounded in physical/lived experience.

2. On instrumental action

Simondon will follow with a proposition that this feedback, this "transfer system between two different orders of magnitude" (140) by which invention happens, can be enacted not only on a first-order-basis relationship between organism and milieu, but also by means of what he calls "adaptation systems" (142). It can rely on external instruments which will mediate the process, in the literal sense of the word: objects might be placed *in the middle* and "link" those two regimes.

Philosopher Carlo Sini, when developing an argument on the role of instrumental work in social and intellectual processes of scientific knowledge production, will speak in terms of an "exosomatic extension", e.g., a tree branch used as stick which "prolongs and thus *enhances* the action of the arm" (Sini 2021, 84, emphasis added). Insofar as instrumental action plays a role in one's process of probing an environment, Sini argues that:

> [...] precisely the inertia of the instrument, its structural limitation with respect to the world, the fact that the world-environment is also much other than "stick-able", points to the infinite improvability of the instrument and the invention of further tools. (84-85)

In this, may we call it, *prosthetic view* on our interaction with technology, i.e., external objects being drafted as enhancers of the body, the "use of the stick teaches the agent about the 'objective' inertia of [a] world [...] endowed with characteristics independent of human agents" (Sini 2021, 84). There is a recognition of the "thickness of things" [*espessura das coisas*] (Padovani 2013, 168), the "thing-y-ness" of things (Baird 2004, 145). Such is the case for Simondon, which will also bring the imagery of the instrumentalised tree branch. He will argue though, that it is only after a first stage where the agent "spontaneously manipulates" the instrument in order to probe its "operative properties", a stage in which problem solving is not the main goal, that the image of an improved stick,

and consequently its fabrication, can be “recruited at the moment of difficulty” (Simondon [1965-66]2022, 148).

It is important though to limit the scope of both propositions, in terms of their applicability. While I subscribe to Sini’s premise that technology, as exosomatic augmentation, is able to act as gauge to an agent’s range of possibilities when navigating an environment, I object to his conclusion, as it fails to break free of a utilitarian, problem solving paradigm. The same, to a lesser extent, can be said of Simondon.

When Sini states that by encountering and experiencing the structural limitations of the stick-turned-instrument it is revealed to us that not everything in the world is “stick-able”, which in turn sets in motion an “infinite improvability of the instrument” via a “progressive complication” (85), what he suggests is simply the crafting of a better stick. Even using a stick, my target is far; therefore, one should improve on it by attaching two branches together in order to reach said target. What that doesn’t account for, is a process of world-sensing where one learns the environment is indeed not stick-able, but it might be brush-able, bow-able, caress-able, left-alone-able. Or that the branch might also serve as fan, writing utensil, or juggling pin. There is still a process of negotiation with the material affordances of the mediator, enacted through a motor-perceptual interaction. In Simondonian terms, we are still operating in a regime where a phase-alignment between organism and milieu does take place. Only now, new operations and interactions with the world are revealed through this newly crafted augmented prosthesis–“If I poke a hole in the branch and spin it really fast, it sounds really cool!”–which don’t have problem solving as both starting trigger, and end goal. There is no clear boulder to be removed here, at least not at first. Technology is interrogated, materials are transformed, and objects are crafted; not purely as resource, but as ways of investigating, discovering, and producing knowledge about possible modes of existence in the world. So, a movement to Simondon’s second “order of magnitude”, one where goal-oriented behaviour plays a role, can happen. But it isn’t the driving force of the process.

If we look at those mediators as *technical-epistemic prosthesis* which will extend and enhance the field of possible world-actions, as well as our conception of the environment around us, the stage is set then for invention to be approached and inquired as a *technologically-mediated* activity, one which will concern itself, to a great extent, with managing the transit between those two regimes.

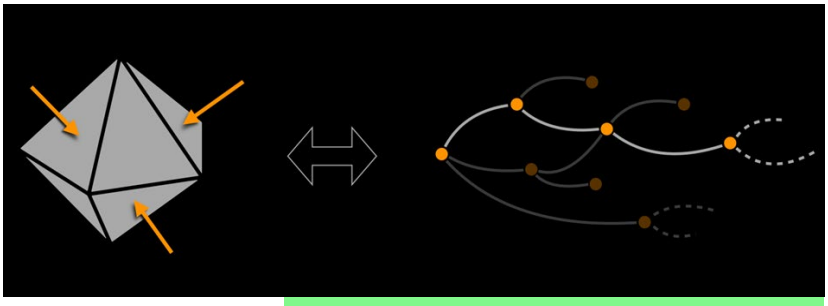


Fig. 1. Two orders of magnitude

3. Tree-traversing

In my practice as experimental music composer / sound artist, and activities as artistic researcher, one of the things I'm interested in is how creative decisions are made precisely when transiting between those regimes, and the role of technology in informing those creative decisions. More specifically, I investigate the consequences of having bespoke instrument building and technology tinkering as the main driving motor of my composition process.

Figure 1 illustrates the described condition: on the left, an object is engaged with by means of free exploration, in a search for *entry points*, i.e., certain characteristics and/or modes of operation of the technology where poietic potentiality is perceived. This process of data gathering while looking *inward* at an object, exists, in tandem, as the root node of a sprawling tree of possible actions; one which moves *outwards* towards a clearer image of what both the composition and its accompanying instrument are, arriving eventually at what I will denominate a *device-work pair*.

3.1. The problem of concurrency

One problem to consider here could be put as one of *concurrency* between the two regimes. The logical circularity between, in Simondon's terms, different orders of magnitude: that of the design of an instrument, and that of the crystallisation of the identity of a composition. A possible paraphrase of Ingold's Marx's dilemma, in this context, could be then "[...] for if the design of a musical instrument being fabricated relies on the role it will play in an imagined musical work which hasn't been yet composed, where does the initial design of the instrument come from?". And because it is a circular causality, the complementary reversed phrasing is also valid: "[...] for if the image of a musical work being composed requires a custom musical instrument which hasn't been conceived yet, where does the initial image of the composition come from?"

On this problem of concurrency, manifested in Figure 1 as a lack of representation of a time domain, one might have the impression that a clear path, a "complete mental image" (Simondon [1965-66]2022,

148) of the intended goal, is present from the start. But that is not the case. There is no clear rolling boulder to be removed here. When I'm investigating a new object (for example, a so-called "obsolete" electronic device acquired at a flea market) the alternation between the two regimes has a much quicker turnaround time, i.e., the frequency of what Simondon will call the "temporary substitution of the instrument-object for the end-object" (143), is much higher, to the extent that calling it "temporary" might not even apply. A more accurate visualisation of the sprawling tree analogy would start with a root node, a single seed if you will, and nothing more. As I engage in "spontaneous manipulat[ion] [...] before any finalized behavior" (148), *events* will occur which will disturb that aimless manipulation. Certain behaviours may stand out for their sonic and gestural potency, or technical properties of the device might draw my attention simply for their pure technicity and my curiosity in learning how they work. Those events then start to add *differences* in what, before, was highly *undifferentiated*. The space of possibilities starts to gain a possible topography, steering my movement into preferred possible directions. So, a discontinuity, yes, but of a different kind. Not one which blocks movement, but one that will trigger me to create/imagine new nodes and their connecting edges. In that sense, my territory is not being organised or structured. It is the *territory itself that is being invented* by a process of inquiring the material affordances of a certain technical device, a process which in turns modulates my own "population of mental images" when I'm deciding what will be my next creative step - even if the end goal is not in sight.

3.2. Revealing borders

Mediation has consequences in two distinct areas, namely the creation process of a work, as well as the work's final form. For the work itself, one can think in terms of an enforced "technographical imprint" [*marca tecnográfica*] (Caesar 2009). A symbolic groove that a technical object leaves on an art object by simply being part of its creation process.

Examples range from early acousmatic music, where the length of loops were a direct consequence of the physical size of shellac disks available at the time, to the non-metric quality of most network performed music, as broadcasting latency makes it difficult for synchronicity between performers. Those are characteristics that are not present in the works as a reflection of the artist's will, but quite the opposite - they're imposed by the devices mediating the creative process. From this observation, I propose an understanding of this condition in terms of a negotiation established between apparatus and

artist along (and through) this mediation, where the artist, by speculating creatively with a device, is presented with the terms with which that device accepts to operate. The creative act is molded, adapted, redefined, according to the discovery of the affordances (Magnusson 2019) present in the apparatus one speculates with. One could conclude then that technology, when mediating art making, reveals its limits, its borders.

3.3. Intuitive relations

One aspect of experimental lutherie which presents itself as an interesting edge case for Simondon's theory, concerns a mode of world-sensing which is not derived of a "perceptual-motor reality", but instead, is built on a relationship to technology which composer and scholar Jonathan Impett will call "intuitive". DIY practices of instrument building often leverage competences from fields such as computer science, by programming and implementing custom software, and different branches of engineering, with the creation and modification of electronic circuits for example. While some artists are indeed professionally trained programmers and/or engineers, many aren't. That implies that inquiring a piece of technology for its artistic potentiality has, embedded in the act, the meta-process of learning what that technology itself is and how it operates. That interaction happens through free activity, where things are manipulated in their material regimes, certainly; but also there is a great deal of "interaction with the *idea* of a thing", where our relationship to technology is based on "partial, reconstructed knowledge rather than direct experience" (Impett 2020). Impett will state that "not only can this idea be wrong, it is crucial to cultural evolution that it is *free* to be wrong, misconstrued, reconstrued", since there lies its novelty, plasticity, and therefore its potency.

4. Conclusion – Inhabiting a border

Simondon recognizes that "perceptual investigation" exists, i.e., one that forgoes direct engagement, although he seems to see it as a problem, since it precludes "adequate discernment of [the mediators] complex operative properties". He will propose that humans have a "constant necessity to confront the partial novelty of situations with an activity of organization of operative modes" (150). What I call attention to then, is a mode of art making which is built on the basis of a *conscious, intentional attitude* of seeking the partial novelty afforded by engaging with technological apparatus: from learning a new programming language, to disassembling a still unknown device. There is a will to inhabit a place which offers resistance and to actively

engage with those borders, since that friction, which comes from material direct engagement with technology, is what will drive the creative act. The border is there, but to be interacted with. Not as a shackle. As succinctly put by experimental music pioneer Alvin Lucier, “no ideas but in things”.

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Data Perceptualization through Affect in Dark Sonification

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Experiencing data through interactive multimodal displays for embodied cognition enables humans to explore and perceive emergent meanings through affect. Inspired by Gendlin's focusing and thinking at the edge methods, this work explores affect in the felt sense, arguing that bodily awareness while interacting with data can facilitate embodied knowledge through pre-conceptual sensory dimensions of meaning. Despite studies in Human Computer Interaction bringing attention to the benefits of focusing on the felt sense for design and interaction, its application remains rather unexplored for interactive data display. In our study, participants interacted with a toy data set displayed via Dark Sonification, an interactive multimodal data display system that is designed to explore complex data through embodied perception. In following interviews, the participants described emergent structures in data reported using sensory language, which contrasts the technical description normally used in exploratory data analysis contexts. Although the findings are exploratory, this work suggests that focusing on the felt sense for interactive data displays can be a valuable complement to traditional methods in exploratory data analysis.

1. Introduction

The field of data display has developed greatly in the past decades as an important part of information science (Enge et al. 2024, 3; Lindborg et al. 2023, 3). However, the predominant approach to data display is often presented to be experienced passively, frequently overlooking how these displays affect human perception and how affect can help uncover meanings in the data, a notion discussed by Lan and Yanqiu in their work on Affective Visualization Design (Lan and Yanqiu 2023, 1-2). In many cases, information display focuses on affect in terms of discrete and measurable human emotional states, nonetheless, interactive and multimodal data display, seen as HCI systems, can help perceive emergent meanings in data not only through emotional responses but also by attending to the felt sense (McCarthy & Wright 2004, 16).

As conceptualized by Gendlin (1978, 32-36) and articulated by Núñez-Pacheco and Poikolainen Rosén (2024, 1029), felt sense refers to a subtle, bodily awareness of complexity which entails an

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embodied knowledge that has not yet been explicitly conceptualized. Techniques such as focusing (Gendlin 1978) and thinking at the edge (Gendlin 2004) can help bring this awareness into clearer form. Accordingly, using them for interactive data displays systems can enable new insights for data exploration through affect. By drawing on Gendlin (1978, 32-36), this paper situates affect in the felt sense, as a more expansive pre- or para-linguistic affective field compared to only emotional response (Massumi 2002, 25-26, 40), to look into the human embodied lived experience for meaning-making in interactive data display systems. Below, we argue that focusing on the felt sense using Dark Sonification, an interactive data display system, can help derive meaning though affect.

Interaction plays a fundamental role in embodied data exploratory systems, such as Dark Sonification, as it can amplify the *naturalness* of the display by creating a bodily connection between humans and information elicited from data (Hermann and Hunt 2004, 5). Such systems are particularly needed in a world characterized by datafication and computation of all human areas of activity (Mejias and Couldry 2019, 1-3), where machines and humans are increasingly entangled (Sanches et al. 2022, 1-2), and decisions with global effect are being made through data insights. From this perspective, how can designers shape these systems to further stimulate an embodied understanding of data, thereby addressing accessibility and inclusion?

Prioritizing data perceptualization through affect in the felt sense could expand data access and literacy capacities empowering users to find meanings in data by focusing on inward affective shifts rather than outward conceptualization, in resonance with Petitmengin (2009, 274). The embodied perception afforded by such systems can enable other ways of knowing and understanding of data, potentially reducing the specialized knowledge threshold required to engage with data technologies (Enge et al. 2024, 8, 22). The role of aesthetics is key for these displays, as it addresses compositional, sensual, emotional, and spatio-temporal threads of experience as reflected by Heimann et al. (2023, 3) on McCarthy and Wright's (2004) conceptualization for data affectivization techniques. Similarly, intent in user design decisions is crucial for choosing the system's output and thus shaping perceptualization (Reed et al. 2024, 2). Yet, is it possible to sense data through our bodies, understanding the meanings that emerge during data exploration in the felt sense?

Núñez-Pacheco and Poikolainen Rosén (2024, 1030) describe this approach to system design as rooted in posthumanism, emphasizing the relational perspective of human-technology. Similarly, Reed et al.

(2024, 2) conceptualize them as *data-enabled artefacts*, conceiving data as more-than-human objects. Hence, interactive display under this line of thought, is a human-data co-created relational space, existing as a vibrant and active embodied environment (Núñez-Pacheco and Poikolainen Rosén 2024, 1030). By turning interaction design attention to the felt sense the designer allows these systems to reward iteration and performativity, enabling an embodied perception in a preconceptual state (Kordeš and Demšar 2021, 339, 344). Consequently, when humans stay in this felt sense during data exploration, they become open to fresh perception and conceptualization of the experience, defined as carry forward steps (Hendricks 2009, 131).

This approach puts the notion of affect in the forefront, as a method for experiencing data within interactive multimodal displays. The resulting phenomena emerging from interaction can be understood as a data-human entanglement affected by context and discourse (Reed et al. 2024, 8), reinforcing data-human relationality based on intent yet constrained by the system affordances. To enable the felt dimension of experience in these systems, data and human must become finely tuned, in what Petitmengin (2021, 175) calls an "affect attunement." Within this attunement, meaning arises from the entangled interaction as experience. In parallel with Petitmenging et al. (2009, 280-281), when attending contextually to the experience of data exploration, the human gradually synchronizes the external and internal space, consequently, deriving data insights emerges from this contextual lived experience. Then, what the human perceives is the data-human relation, and the meanings derived from data exploration are closely related to this experience.

Building on the framework of affect attunement, we conducted an experiment where a selected group followed a set of instructions based on focusing (Gendlin, 1978) and thinking at the edge methods (Gendlin, 2004) to engage in exploration with a toy data set using an interactive multimodal data display technology, Dark Sonification (explained in more detail in section 3). The goal of this experiment was to assess whether interactive data display systems can benefit from thinking design of affect in the felt sense, adding a meaningful dimension to data exploratory display systems beside the emotional and conceptual. To this end, the system aims to reinforce the multiple ways of bodily knowing, addressing the experiential dimension of knowledge (Gendlin 1970, 561-563).

Moreover, this experimental study builds on our previous work on the use of data-to-sound representation (sonification) as an interface for music composition and performance (Crozzoli & Magnusson 2024).

There, we explored our design choices guided by the project's intent to create an aesthetic sonification, and their further use as material for music composition and sound source for musical performance. With Dark Sonification, it is possible to design perceptual attributes that express the mathematical grain of a data set as the affective grain of a performance and focus on bodily shifts as compositional and performative pseudo-structures, parallel to Isadora Duncan's kinesthetic impulse to follow and create movement (Berger 1992). Furthermore, the study invites traditional exploratory data analysis to incorporate the felt sense by addressing the performative side of data exploration. Whether data perceptualization through affect focusing in the felt sense is experienced in a gallery, studio or control room, knowledge is carried forward through embodied perception of data through exploration in performativity. Therefore, one of our central questions for this study is: How do participants notice, describe and make sense of the bodily shifts that occur while exploring data with dark sonification?

2. Context

Efforts in the data display community have focused on bridging data representation capabilities with more user-friendly systems. However, this often comes at the expense of flexibility in data manipulation and customizable display possibilities (Armitage et al. 2024a, 18-20). Moreover, current tools still rely on a certain level of specialized knowledge to operate them and infer information from data interactions (Enge et al. 2024, 22-23). Thus, adding interaction capacities to the display of complex data has shown an increase in efficiency, effectiveness, and user satisfaction (Pauletto and Hunt 2009, 932), yet most of these interactive systems tend to focus on embodied cognition through affect as emotional response rather than the felt sense.

Interactive data display projects could further benefit from integrating the felt sense in design, especially looking into Human Computer Interaction (HCI) research that study the felt sense. Núñez-Pacheco & Poikolainen Rosén (2024, 1029) noted that while the felt sense has been studied in HCI from a human-centred perspective, it remains unnoticed in relation to the non-human or more-than-human agents. Correspondingly, Reed et al. (2024, 8) emphasize ambiguity and open-endedness in design to bring attention to non-human agents. Making the case in favor of recognizing non-human agency, these systems use symbolic and sensory input while preserving the flexibility for humans to co-create meaning through embodied interaction. However, a challenge to include the felt sense for data exploration is that first-person experiences are often met with skepticism in sci-

entific contexts due to their subjectivity and associated bias (Gallagher and Zahavi 2012, 6). Nevertheless, focusing (Gendlin, 1978), thinking at the edge (Gendlin, 2004), and micro-phenomenology (Petitmengin, 2006) have emerged as methods to access and distil information from the felt sense in a structured manner, yet their application to interactive data displays has remained limited.

This paper focuses primarily on the human for embodied, affective dimension of data perceptualization. Hence, creating a system that positions data and humans as co-creators in an interactive display requires an open relational space grounded in design transparency and intent. In practice, this means to render visible human intent within the design workflow and enable data to express its agency. In this context, Reed et al. (2024, 4) frame these systems as *Baradian apparatuses*, where data as a material provides clarity for the design process. Similarly, Sanches et al. (2022, 1-3) propose data-driven design based on Barad's agential realism as a way to attend to the materiality of data for design purposes. Dark Sonification adopts these conceptualizations to create a display system as a data-human relational and performative space that dissolves boundaries between inner and outer experience (Hendricks 2009, 152). Here, both human and data intra-act to co-create an enacted, entangled environment.

This vision aligns with the post-interaction paradigm in HCI, which Sanches et al. (2022, 2) describe as a shift towards designing systems for and with computing, focusing on background services that allow for interaction. This paradigm manifests on the increased entanglement between human and machine in contemporary society, where human and material –such as data– are interconnected creating ongoing and emergent phenomena (Sanches et al. 2022, 1-2). Reed et al. (2024, 5) defines designing in post-interaction as creating open-ended practices of conceptualization rather than deterministic apparatuses, allowing for dynamism and flexibility, which Dark Sonification subscribes to.

Within this framework, aesthetic decisions play a fundamental role in shaping affect through intent in data display design (Crozzoli and Magnusson 2024, 119-121). Extending this point, Reed et al. (2024, 6) argue that aesthetics influence meaning-making via embodied design, which in this experiment takes the form of data exploration. Similarly, Supper (2014, 35) argues how aesthetic strategies can deepen our understanding of data. Building on these insights and Heimann et al. (2023, 3) discussion, we articulate that aesthetic decisions unfold along compositional, sensual, emotional, and spatio-temporal threads of experience (McCarthy and Wright 2004, 79-94) helping to attune

humans into the felt sense though affect. In this experiment, we explore the relevance of such attunement for data display systems, arguing that it enables a finer embodied engagement with the data.

The person engaged in data exploration within this type of system experiences the emergence of meanings in a pre-conceptual state, which they perceive as shifts in their bodily awareness. Embodied processes of knowing then become inscribed in what Kordeš and Demšar (2023, 348) describe as the horizon of attending experience. In this view, horizons delineate how the experience unfolds within the entangled environment shaped by the system's affordances. The felt sense, in turn, is dynamically configured within these horizons, guiding the perceptual dimensions of an ongoing human–data enactment. Consequently, meaning emerges from the interplay between human-experiencing and data, in parallel to Gendlin's (1970, 561) conceptualization that *meaning emerges from the interaction between experiencing and symbols or things.*

Existing interactive systems have worked with embodied cognition and affect, though not always focusing on felt sense. For instance, Sonic Cradle (Vidyarthi and Riecke 2013), an exploratory design using participants breath to investigate meditative attentional pattern, and its follow up project Sonic Cradle - Immersive interaction design combining breathing- and neurofeedback to foster focused attention meditation on breath (Prpa et al. 2016) which integrates live electroencephalogram data from the user to detect the participant focused attention to interact accordingly and create a proper meditation space. Soma Mat (Höök 2018) directs bodily attention with heat following a pre-recorded Feldenkrais lesson, guiding users' awareness toward their bodily states. Wakkary et al. (2018) introduce the tilting bowl as a digital artifact that provokes philosophical co-speculation on human–thing relations, and Liu et al. (2018) adopt a post-anthropocentric perspective to explore human–fungi collaborations, positioning technology as part of a broader ecological relation. Additionally, in line with xCoAx's ongoing dialogue between computation and affect through embodied artistic practice, Hedayati (2023) collects biosignals while viewing emotionally charged footage of protests in Iran. These data are later sonified, expanding an inner experience of trauma into a shared, collective sound-space. While these projects address different aspects of affect, embodied, relational, and more-than-human interactions, they do not explicitly center on the felt sense, nor do they function as design systems for exploratory data analysis.

Dark Sonification is positioned within the discussed context, as a post-interaction technology for designing data displays that conceptu-

alize data as a non-human agent and rewards performativity for embodied cognition through iterative and attentive exploration of the apparatus' relational output. The experiment in this paper makes use of Dark Sonification affordances to explore data perceptualization though affect in the felt sense, and tries to advocate for awareness of the felt sense as a valuable incorporation to data perceptualization though affect.

3. Dark Sonification

Dark Sonification, is an explorative intelligent system designed for uncovering emergent meanings in complex and big data sets through interaction and multimodal display. The project aims to create an accessible data perceptualization system based on machine learning algorithms and deep learning to decode complex structures within big data, and representing these findings through auditory, haptic, and visual feedback. Influenced by the concept that data should be viewed as capta (Drucker 2011, 2-9), this project emphasizes the subjective nature of data, building an ecological human-data environment based on interactive exploration. The project is inspired by data democratization (Lefebvre, Legner, and Fadler 2021, 2-5) aiming for engagement and embodied knowledge as a mode to perceive and understand data.

The architecture of the system involves multiple interconnected intelligent engines: Processing, Mapping, Navigation, and Display. The Processing engine employs libraries like Scikit-Learn for machine learning tasks and PyTorch for building deep learning models, to create a dataset for perceptualization by identifying and decoding structures within big data. The Display engine transforms this processed data into sound, visuals, and haptic feedback, using sound synthesis programming language such as MaxMSP (Puckette 2002) and SuperCollider (McCartney 2002) for sound display, and Tölvera, a powerful Python based ALife library for visualization (Armitage, Shepardson, and Magnusson 2024b, 2-5). The Mapping engine connects the latent spaces generated by the Processing and Display engines, enabling dynamic data representation through customizable mappings between both spaces based on Machine Learning algorithms, such as K-Nearest Neighbours (KNN). The Navigation Engine uses physical controllers, such as gaming and musical instruments, as input for the Mapping Engine, allowing users to navigate Dark Sonification's display.

Dark Sonification is based on a pipeline structure. In its workflow, the human takes analysis, design, and interaction decisions before running visual and sound display engines in parallel (see Fig. 1). The

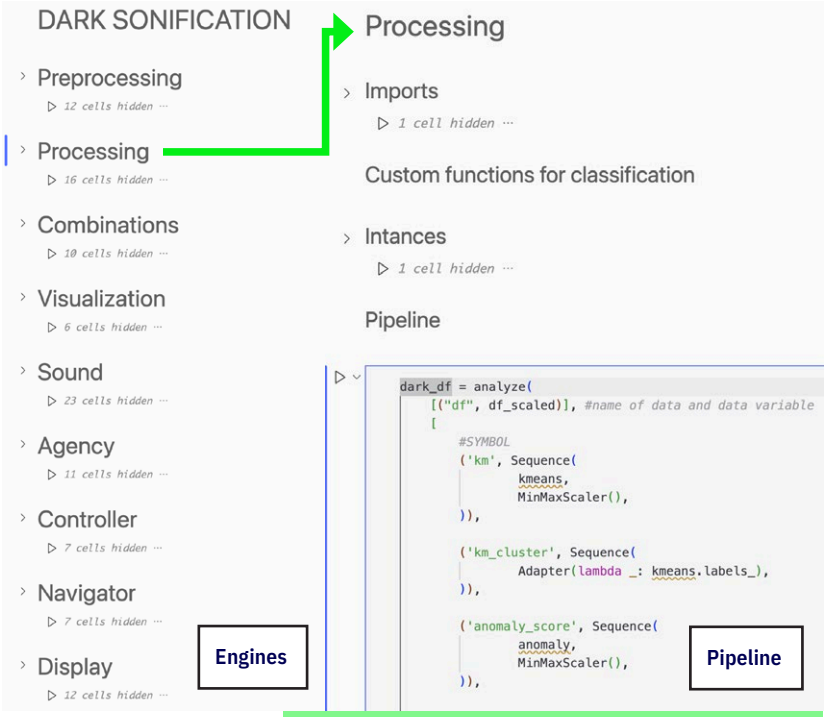


Fig. 1 Dark Sonification Jupiter Notebook structure displaying engines collapsed to the left and Processing pipeline example to the right.

decisions made in the pipeline, will produce a defined range of possible interactive environments. This can be of advantage when strategizing variability for multiple display outputs. These strategies can range from creating detailed customizable mappings where the human decides every aspect of the data translation into display, to mapping data structures through machine learning algorithms and interaction traces with a dense neural networks architecture, where the system self-assigns mappings between engines based on data-human intra-action.

Furthermore, the pipeline can be dynamically modified, allowing the human to change mappings strategies, controllers for navigation, and display types in real time to perceive different structures through different means. Another essential feature is the implementation of interaction traces, which monitor human navigation paths. These traces update maps of attention, influencing macro features of the display such as visual behaviors or more silent spaces for sound corpora navigation. This functionality enables the system to adapt its outputs to reflect the emergent dynamics of the data-human entanglement.

3.1. Affect in the Felt Sense in Dark Sonification

As mentioned previously, one of the main strategies of Dark Sonification is to create a dynamic structure based on human-data intra-action, conceptualized as an environment. In this environment, the embodied controller works as an interface for human-data communication and is this what creates affect in the felt sense. Thus, each interaction allows for the emergence of subsections of this environment as a perceptual field, which is what it is perceived as displayed output. The perceptual field is where affect occurs, and it is defined by its content and shape.

Through interaction, the field properties are continuously updated.

The content of the perceptual field is based on subsections of columns of the data returned by the processing engine. By updating this content through navigation, the space of what can be explored and perceived changes. Interaction also updates the shape of the perceptual field, creating boundaries for the human to experience data within. Each interaction transforms the human perceptual awareness, reinforcing the relational nature of Dark Sonification data exploration. This process is iterative, which is central to Dark Sonification, as it highlights how meaning is co-constituted through continuous human-data interaction.

The perceptual field allows for performative and active engagement which enable humans to perceive data not as an external object but as an extension of their own subjective perception, ultimately becoming one with the data through the perceptual dimension (Petitmengin 2021, 173-174). Based on Petitmengin (2006, 234), here perception occurs within a pre-reflective domain, where bodily awareness precedes conceptualization. Therefore, this experiment focuses on finding shifts in this perception to understand meaning-making processes in a state of pre-conceptual, contextualized in data exploration.

Accordingly, interactivity is situated at the core of this experiment. By making use of gaming controllers to allow interactive and embodied data exploration, we enable an affective co-agency between perception and bodily movement, which Stuart (2015, 103) describes as enkinaesthesia. This co-agency emerges from the entangled experience of actions between objects, being objects human, non-human, or digital (Stuart 2015, 104-105). In Dark Sonification, the act of navigation with the controllers feeds a continuous loop between perception and interaction that become dynamically interrelated within the perceptual dimension of the human, further articulating entanglements between human and data, and both with the system's environment. Based on human-data intra-action in the Dark Sonification workflow, the system crafts an environment that can be thought of as an entangled relational space that allows for interaction. The system's output unfolds based on human-data enactment and system's affordances with dynamic adaptations.

Consequently, by attending to their bodily shifts while interacting with the system, humans access a process that is felt, a pre-reflective mode of embodied knowing through a co-constituted process of relational engagement with data, echoing Schoeller's (2024, 24) reflexive care.

4. Experiment Set-Up

The experiment was designed to understand the value of focusing on the felt sense for data exploration in Dark Sonification. Based on Focusing steps (Gendlin, 1978) and Thinking at the Edge movements (Gendlin, 2004), we structured the test into four stages with a set of stage-specific instructions intended to guide participants toward an inward-body awareness. These stages were adapted from Hendricks' (2009, 131) Experiencing Level, which outlines three steps: sensing the felt dimension, recognizing a felt shift, and carrying forward. For this experiment, we added a zero stage to create and guide the participants' awareness to their body to facilitate data-human attunement for the following stages. The four stages are:

- *Stage 0:* Introduction / Clearing a Space: At this initial stage, participants transition from noticing their external surroundings to sensing their bodies through guided breathing exercises. The stage is considered complete once the participants feel aware and connected of their bodily sensation.
- *Stage 1:* Sensing the Felt Dimension: In this stage, participants take the controller and begin exploring data while keeping attention to their bodily sensations. The participant is encouraged to notice the system's sonic and visual feedback through questions like, "How do I sense this data right now?" or "What happens in my body when a particular sound occurs?" The goal is to remain open to how the data feels.
- *Stage 2:* Felt Shift & Handle: Once participants detect a change in their bodily sense (a felt shift), they pause to let the sensation be. They can move away from the data point, then return to it, to notice if the shift persists or evolves. Next, they attempt to form a handle, such as a word, phrase, or image that resonates with the bodily experience.
- *Stage 3:* Carrying Forward: If participants arrive at a word or image that meaningfully aligns with their bodily sense, they pause to acknowledge it, breathing with the felt shift, and let it unfold. At this stage they can take notes, make voice recordings, or save the index of the data point for later conceptualization. Once they articulate the felt shift, they can return to Stage 1 to continue navigating the data or end the exploration.

While stage 0 is meant to be done only once, stages 1, 2, and 3 are repeated in a loop.

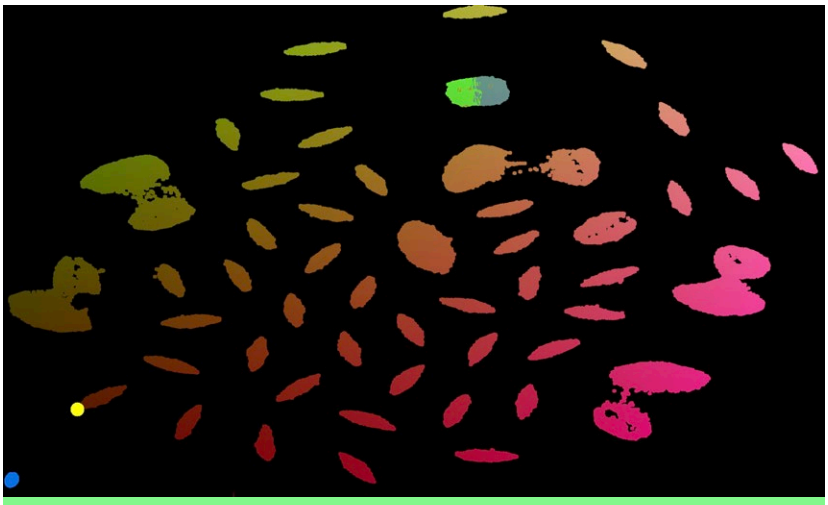


Fig. 2. UMAP dimensions plotted with Tölvera for interactive data exploration



Fig. 3. MaxMSP patch to process incoming data from Dark Sonification with a RAVE model

4.1. Data and System Configuration

We designed a display system based on a controlled toy dataset emulating time series weather data. The dataset consists of 150,000 rows and 10 columns, divided into three clusters, with 10% of the total data points classified as anomalies. In the processing engine, clustering was performed using the K-Means algorithm, and anomalies were detected with Isolation Forest, both imported from SciKit-Learn library. The dataset was also reduced to two dimensions using Uniform Manifold Approximation and Projection (UMAP).



Fig. 4. PlayStation 5 Dual Sense controller used for interactive navigation with the experiment's display

The visual design was constructed as a scatter plot generated with Tölvera, mapping UMAP dimension 0 to the x-axis and dimension 1 to the y-axis. RGB and alpha values were assigned based on cluster id and distance to main cluster for each data point, while anomalies were highlighted using differentiable colors from the clusters (see Fig. 2).

For the sound design, the UMAP dimensions were mapped directly to the latent space of a RAVE (Caillon and Esling 2021, 5-8) model using a KNN algorithm (see Fig. 3). This generated an identity drone sound unique to each data point. These sounds were further pro-

cessed with reverb and delay effects to enhance each cluster's and anomalies' auditory texture and spatial depth. All data used to map the audiovisual display parameters was the data returned from the processing engine.

For data exploration, in the experiment the participants used a PS5 DualSense controller (see Fig. 4), with only the left joystick enabled for navigation to maintain simplicity in interaction. While Dark Sonification supports multimodal feedback, for this study, we focused on audiovisual display, deactivating the system's haptic feedback to minimise cognitive load and keep participants' attention on the inward, felt shifts prompted by the audiovisual pairing.

Overall, the mapping strategy keeps the visual and sonic output synchronized by anchoring them to UMAP components. In this experiment, each x and y position in the plot correspond to a unique latent representation in the RAVE model. Therefore, navigating left-to-right or up-and-down on screen steers the listener through correspondingly unique drone timbres. Additionally, colour saturation encodes each point's distance from its cluster centroid, giving every cluster a recognisable color identity matching spatial latent distribution of our rave model.

4.2. Participants

Four participants were recruited based on diverse criteria, including their prior experience with data displays (as either users or designers), their familiarity with Dark Sonification, and their familiarity with practices addressing directly or indirectly the felt sense, such as focusing or meditation.

4.3. Test Flow

The experiment was conducted with one participant at a time to ensure a controlled and focused environment. Each session took place in an undisturbed setting, with consistent arrangements maintained across all participants. Participants were scheduled on different days to ensure time flexibility if required. At the start of each session, we provided a brief introduction to the technology and the experimental stages, explaining the purpose of this experiment.

The experimental procedure was structured around the designed four stages. Stage 0 was guided by one of us, helping participants to focus on their bodily awareness. In stages 1 to 3, the participants explored the data independently, applying the provided instructions in stage 0 to attune to bodily sensations during exploration (see Fig. 5). If for any reason the participants needed to refocus on their bodily

awareness, they had next to them a printed page with instructions for how to refocus. Participants were given 20 minutes to explore, though they were allowed to end the session earlier if they felt their exploration was complete or felt uncomfortable with the experiment. After completing the exploration, participants were given a pause to process their experience, followed by a semi-structured interview.

5. Interview

Following the exploration phase in Dark Sonification, each participant took part in a semi-structured interview designed to extract insights from a first-person experiential account. Based on micro-phenomenological techniques (Petitmengin 2006, 239-258), these interviews sought to explore the temporal unfolding of participants' bodily sensations, with a particular focus on identifying felt shift during stages 1 to 3. The methodology involved taking notes, repeating key phrases back to participants, recapping narratives as needed, allowing space for silence, and posing how-oriented, open-ended questions to encourage articulation of subtle changes in the felt sense. All interviews were audio-recorded and later transcribed. First, diachronic description of each session was produced, slicing the transcript into succes-sive experiential units to preserve its temporal flow. Then synchronic comparison across the four narratives was done, looking for recurring markers of felt shift such as tension/release or cross-sensory image-ry. Because the coding was handled by a single analyst, the findings remain exploratory yet fit the study's exploratory aim.

Based on the conducted interviews, we can suggest that the use of Dark Sonification together with the designed stages and their instructions, facilitated an embodied awareness for interactive data exploration. Participants described their experiences through rich bodily descriptions, imagery, and metaphors, generally comparing the experience to a meditation practice.

A recurring theme was encountering zones of "tension and release" in the data display. Participant 1 noted, "I started to look for sounds that would release some of this tension...I would find the spots that were opening up and (deep breath) now I can breathe out again and reconnect." Similarly, participant 2 characterized his experience as "a constant game between tension and release while I was searching." and Participant 4 noted how some areas made her feel "heavy in the lower back," whereas others "light and airy." Both Participants 1 and 2 referred to certain data points as



Fig. 5. Participants interacting with Dark Sonification for data exploration after stage 0 was completed.

"safe zones." These observations confirm the participants' body awareness and the affect of the display in their bodily state.

Another outcome was the cross-sensory associations participants reported, particularly with smell. Participant 1 recalled detecting "palo santo," even though there were no odors in the experiment room, while Participant 2 perceived "changing smells...metal, maybe the room, air-conditioned smell," despite the system having no olfactory output. These observations align with Petitmengin et al. (2009, 282-283) notion of transposability across senses, indicating that hearing and/or seeing was transposed to olfactory sensations, suggesting a fine data-body attunement.

Participants also articulated metaphors and mental imagery tied to specific sonic or visual clusters. Participant 3 described perceiving data points as "spiraling downwards" or "flying through space," while participant 4 referred to "a sense of aura." These descriptions correspond to multimodality in the felt sense, which Petitmengin et al. (2009, 277) articulate in the felt sound.

Some participants also noticed memories linked to places tied to specific points of exploration or transitions between points. Participant 1, for instance, mentioned memories of pine trees near an Italian seashore. This recollection can potentially unfold contextual meaning-making of the data point if the participant unfolds the experience.

Moreover, two participants mentioned focusing on their heartbeat while navigating. Participant 4 stated, "When you think about it, you're like, 'Oh, there's my heart,' and it kinda pulls you down to Earth. I felt it more in those in-between moments moving around the display, not really sure what I'd find. But noticing it now actually centers me." This illustrates a synchronization of inner and outer space while experiencing in the felt sense, paralleling Petitmengin et al. (2009, 273) regarding experiential space of the felt sound.

More abstract and increasingly interesting reflections also emerged during the interview about how this approach could be used. Participant 1 compared the experience to "a ritualistic scenario...where you need to prepare in order to be welcomed," in line with more-than-human ethics proposed by post-human studies. Participant 4 speculated on applying this experiment to mundane spreadsheet tasks, emphasizing, "I think it could give me a lot...acknowledging everything around you has a lot of impact." Such comments highlight the participants' curiosity about integrating embodied techniques into different scenarios of data handling, thereby expanding conventional definitions of data literacy and entering in the terrain of data ethics.

Overall, during the interviews, descriptions from the participants diverged from traditional data-analytic language. Instead, participants framed their insights via bodily shifts and sensory impressions, consistent with the pre-conceptual articulation that the experiment sought after.

6. Limitations

Despite these rich observations, there are limitations to the experiment. First, even with the diverse background and expertise of the participants, the sample size for the study falls short, limiting generalization of our findings. Second, focusing on the felt sense might be difficult in a real-world scenario, and domain-specific knowledge could also create a barrier to allow a more ludic approach to data exploration, putting in doubt the applicability of such techniques for data exploration. Third, one participant struggled with wearing headphones at the beginning, which required re-focusing on their bodily sense. Offering more training time or different interfaces based on participants' capacities needs to be implemented to mitigate circumstances. Additionally, this paper theorises and exemplifies the value of working with the felt sense in data-display systems rather than an exhaustive study of parameter-mapping strategies for designers to work with the felt sense. We identify this as a potential study, applying the structural analysis of listening to the felt-sound proposed by Petitmengin et al. (2009) to concrete mapping scenarios.

7. Conclusion

After conducting this experiment, we can suggest that focusing on the felt sense for data perceptualization through affect is a valuable complementary method to traditional approaches in exploratory data analysis. By engaging participants in embodied awareness for data exploration, our study showed a pre-conceptual dimension of meaning-making; rich in sensory experiences that describe a structural and personal perception of the data. The results offer insights into a reflective layer of data exploration articulated through sensory language, in contrast to the technical language typically used in conventional exploratory data analysis.

Different fields can make use of this sensory experience based on intent in their data exploration project. While it can be easily adapted in the context of information dissemination and artistic expression, scientific data exploration contexts might require a more refined understanding of its usability. A straightforward implementation is to begin each data exploration with clearing-the-space, as explained in stage 0 in Section 4, allowing users to attune to their embodied awareness before the system activates. Moreover, using pencil and

paper to take notes, or allowing the system to save data indices and record voice memos can help users to capture when the felt-shift occurs. These notes and logs can later be revisited alongside conventional analytics, turning subjective insight into a traceable design asset. Nevertheless, we suggest that further studies are needed to compare insights derived from the felt-sense in data exploration with those from traditional methods, using a control toy data set as a benchmark. In our view these studies are not meant for accuracy, but to understand which other complementary data insights we can find through focusing on the felt sense. Interestingly, our participants expressed a strong interest in tools that facilitate human-data engagement by focusing on the felt sense. Future studies should also explore how embodied techniques, such as focusing and thinking at the edge, can be integrated with other data analysis methods.

Ultimately, this study encourages the investigation and inclusion of diverse embodied ways of knowing to create more and different modes of accessing data. In times of global polycrisis, where major decisions are driven and controlled by data insights, expanding strategies of interaction and perception is a necessary act for community empowerment.

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Timbre: Transforming Perception into Sonic Expression

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The recent surge of interest in timbre studies has exposed a fundamental problem in its conventional framing: timbre is neither an inherent physical property nor merely a response to acoustic stimuli. Instead, it emerges as a contingent relationship between the listener and the sound event, shaping individual auditory realities. This paper challenges traditional perspectives, using sound art to explore a radical subversion in which timbre is understood as an expression of the cognitive structures that shape auditory perception. The sound installation *Sonic Iterations for Intangible Existences: Dark Matter* explores this paradigm shift by speculating on the possible timbral behaviors of sound in dark matter—a medium with no prior acoustic references. By transforming mental timbral constructs into acoustic physiognomies through Smalley's transformational discourse, the work externalizes the internal frameworks that govern individual perception. In doing so, it raises two key questions: Do the results reveal that our auditory realities are not immediate perceptions, but iterative constructions? Have we encountered an expressive dimension beyond the reach of current technology? This study suggests that timbre is not a fixed physical attribute but a possibility for building worlds.

1. Introduction

"Perhaps there is no thing in itself, only interpretations of the thing, or the way we perceive it, or feel it." (Maia 2024) This is the first phrase that is heard in the sound installation *Sonic Iterations for Intangible Existences: Dark Matter*. The reason I chose to start the article with this sentence, or seemingly vague thought, is because, in the end, it revealed itself through sound art, a perfect expression of the contingency that governs timbral perception, while also mirroring the research process itself. Throughout its academic and scientific heritage, the "problem of timbre"—the cherished term for the inability to define it—has always manifested itself tacitly. The apparent inconsistencies in how we explain this concept have always hinted that this *thing* we seek to describe, after all, is neither universally described nor universally experienced. Timbre, therefore, continues to be an amorphous concept, which expands and compresses with the advance of technology, society and in turn, art itself, causing its knowledge

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to often be developed under apparently very distant and repellent philosophies (Wallmark 2020). An example of this was the surprising conference “Timbre is a Many Splendored-Thing” which, as well as demonstrating a pick of resurgence of interest in this topic, brought together a panoply of researchers from the most diverse fields, including psychologists, composers, theorists, historical musicologists, ethnomusicologists, popular music scholars, performers, computer scientists, and acousticians to each debate their own perspectives on timbre (Thoret et al. 2018). However, our resistance to a truly comprehensive vision that admits and articulates its various forms, or the natural tendency we have to try to circumscribe the concept along defined lines, is part of the reason why there still doesn’t seem to be a consensus. And I say “seem”, because in fact, a larger consensus is manifested surreptitiously across all the many different areas of study that have focused on timbre in recent years (McAdams 2018):

Timbre is not liable to an absolute definition.

Therefore, in this study we embrace its indeterminacy and focus instead on exploring it as an individual expression of the contingent relationship we establish with the sound event.

Sonic Iterations for Intangible Existences: Dark Matter is a timbral speculation sound installation that emerges as a radical subversion of the conventional study of timbre. It proposes a methodology that liberates timbre from the saturated perspective that confines it to a mere response to acoustic stimuli, allowing it instead to express the pure mental operations inherent in how we “timbre” our auditory reality—A wordplay inspired by the Portuguese verb “timbrar[1]” which signifies an imposing action rather than a passive one.

1.2. “Perhaps There Is No Thing In Itself”

To navigate the elusive concept of timbre, it is often defined as that auditory sensation that allows us to distinguish between different sounds, even when pitch and intensity are similar (ANSI/ASA 2013). Many before me have pointed out that the prevailing issue of this definition is its negativity, defining timbre more for what it is not (Dolan 2018). I disagree, the prevailing issue is its latent ambiguity. This definition attempts to describe timbre while avoiding excluding anything from it. Instead, it leaves us with the impression *that perhaps timbre is no thing in itself*, but our individual interpretation of the whole. The term becomes a depiction of an all-encompassing auditory sensation that, while not representing all of what sound is, nevertheless reflects the articulation of all sound attributes and our subjective interpretation of them.

1.3. “Only Interpretations of the Thing…”

This perspective places timbre at the perceptual end of the auditory process, existing solely as a mental construct, aligning with the current views on sound source identification.

As McAdams’ studies have consistently shown, timbre plays a central role in perceiving, identifying, fusing, and segregating sound sources (McAdams 2013). However, timbral perception does not follow a linear process, nor does it always faithfully translate the acoustic stimulus that trigger it.

Identifying and characterizing sources through timbre is generally robust and effective, particularly in ambient listening mode, essential for daily survival and navigation (Gaver 1993). However, Smalley’s framework of spectromorphology (Smalley 1997) suggests that in other listening modes, such as when listening to music, the stability of source-bonding —the cognitive act of linking perceived timbre to its material cause—is disrupted, often leading to inferred or imaginary perceptions of the source. These perceptions can deviate entirely from what the acoustic signal represents in the physical world.

These dissonances in timbral perception are vividly explored in the fissuring “The Paradox of Timbre”, where Fales (2002) argues that while we can identify sources, what we perceive is a mental version of the source, one that does not always correspond directly to its acoustic reality under any measurable standard. This is exemplified by two key timbral anomalies: extraction and redistribution. In extraction, isolated partials are removed from a sound, yet the listener still perceives the original source, revealing that timbre is reconstructed cognitively rather than being entirely dependent on the acoustic signal. In redistribution, partials from different sources fuse into a single entity, demonstrating that timbral perception can completely override the physical distinction between sounds.

In chasing the essence of timbre, the above exploration of its perceptual operations finds a strong resonance in Voegelin’s philosophical notion of sonic possible worlds. In philosophy, contingency refers to something that exists as it is but could have been otherwise—its form is neither universal nor determined (Voegelin 2014). For Voegelin, listening operates on this same plane; it is not a fixed inevitability of the physical world but a possibility for its interpretation. The form timbre takes in the listener’s mind is neither assured nor necessarily the same in all possible worlds; instead, it emerges as an individual truth unique to each listener. Perceived timbre, then, reveals itself as an expression of the mental structures that shape our experience of the sonic world.

2. The Missing Perspective

This realization exposes a structural flaw in timbre studies: they often analyze a timbral perception already corrupted by the strength of acoustic stimuli. A source—real or synthesized—produces an acoustic signal carrying a set of cues that activate cognitive listening processes. These processes interpret the information heuristically, generating the most plausible hypothesis among multiple possibilities (Bregman 1990). Thus, perceived timbre always emerges as a result of the tension between the force of the acoustic signal vs. the interpretative power of the mind.

This presents a problem when attempting to access mental timbre—the pure, untainted core of the cognitive structures that shape our auditory reality.

Few studies focus on timbre's mental dimension before it is influenced by the acoustic stimulus. A rare exception is the very recent "Comparison of Heard and Imagined Blends of Instrumental Dyads" (Zhu and McAdams 2024), which marks a much-needed paradigm shift. By comparing imagined and heard timbral blends, the study shows that imagined timbre is contingent on the listener's individual relationship with the sound source. Rather than a mere echo of past auditory experiences, imagined timbre is an active reconstruction—an interplay between memory and internal simulation—resulting in a perceptual outcome distinct from what is physically heard. This reinforces the view that timbre is not a product of external sound but an already existing cognitive construct that shapes unique auditory realities.

2.1. Subversion

Such a perspective requires subverting listening paradigms. This means that timbral perception becomes an active, although preattentive act (Fales 2002) that colours the very reality we perceive. The fact that our everyday listening makes it seem as if the opposite is true, i.e. that what we hear is only what we pick up from the acoustic world, shows the ability of our mind to hide from us its own role in perceptualisation, the very process of generating coherent auditory realities from fragmented signals.

Perceptualisation, as Fales defines it, encompasses the set of cognitive mechanisms that transform the acoustic stimuli into mental percepts that deviate from their physical existence. These mechanisms construct cohesive auditory experiences, often fabricating timbral qualities to resolve ambiguity. Fales also points out that one of the

greatest ironies of perceptualisation is that it is tuned to convince the listener that this process doesn't exist and that the "virtual" timbre we perceive is the real version of the acoustic stimulus that causes it.

3. Methodology: "Or the Way We Perceive It, or Feel It."

To transform timbre from perception into external expression, we turn to art. If constructivism sees knowledge as actively built through interaction between the individual and his environment, (Cresswell 2014) art makes this process evident. Throughout history, artistic expressions like painting, sculpture, and even photography have externalized how artists capture and interpret the world. Like other forms of expression, art begins with perception. We are inspired by what we experience, expressing the way we perceive it, or feel it. In some ways, it could be considered a way of making our thoughts perceptible, both to ourselves and to others. In fact, Max Beckman speaks of painting as the fixing and transformation of those "immaterial" events of his own thoughts, feelings, memories and responses into something more material (Belting 1989).

This became the starting point for our methodological approach. A sound art piece where the immaterial events of timbral perception that colour our auditory realities—our own thoughts, feelings, memories—could be materialized.

Consider Vincent van Gogh's Starry Night. According to a scientific hypothesis, this painting is a very close visual representation of the principle of turbulence, a scientific theory that demonstrates the movement and flow of particles in conditions of high turbulence (Ma et al. 2023). In this case, it is argued that Van Gogh's painting could express, in an unconventional way, the complexity of this until-then intangible phenomenon, as if the artist had captured an essence not yet observable to the human eye, but present in the world. Whether intentional or not, the painting captures an essence previously unobservable, revealing the world through perception rather than objective analysis. Art, in this sense, makes the being manifest in a unique way, revealing internal correlations and meanings that construct the artist's perception of the world.

4. Sonic Iterations for Intangible Existences: Dark Matter

If *The Starry Night* could provide a glimpse into how Van Gogh conceived his reality through his visual representation of the invisible phenomenon of turbulence, then an audible representation of

an equally intangible phenomenon may similarly offer a glimpse into how we timbre our auditory realities individually. Dark matter, one of today's greatest mysteries in physics, emerges as the epitome of this intangibility: an existence, that despite constituting most our universe's mass-energy content, neither emits, reflects, nor absorbs light, remaining invisible by essence. Its form is unknown, nevertheless holds multiple possible representations in the mind of each person that studies and interprets it (Bertolami and Gomes 2017).

This became the concept that shaped the sound installation. Drawing inspiration from Kubisch's *Electronic Walks* (2003)—works that revealed the hidden electromagnetic dimensions of our world—I too intended to generate possible sonic representations for the elusive dark matter. However, instead of an electromagnetic sensor capturing and translating these dimensions into sound, as in the case of *Electronic Walks*, it is the internal structures and sensory processes of the mind that will generate the acoustic physiognomy.

In quantum physics, the principle of superposition demonstrates that a quantum system can exist in multiple states simultaneously—until it is observed (Caltech Science Exchange 2025). Timbre perception, to me, follows a similar principle: it holds multiple possibilities for representing the momentary state of some *thing*, but it is only when we establish a conceptual relationship with the sound event that we collapse all these possibilities into one—our own perception of that *thing*.

As corroborated by Orfeu Bertolami in a personal communication (October 27th, 2023):

"Timbre is our interpretation of matter, and its state as manifested through mechanical waves."

This concept was awarded in 2023 by Digitópia's Utopian Laboratory project and premiered in October 2024 in the west wing of Casa da Música during the Porto Electronic Music Symposium, with the attentive guidance of Óscar Rodrigues, Digitópia's curator and team leader, throughout its conceptual and technical development.

4.1. Strategies for Painting an Auditory Reality

To establish a conceptual foundation for approaching the enigmatic nature of dark matter, a series of meetings were conducted between October 2023 and July 2024 with Professor Orfeu Bertolami, a renowned theoretical physicist and dark matter specialist at the Faculty of Sciences of Porto University. While the physical inter-

action between sound and dark matter remains highly improbable, our discussions sought an equilibrium between speculation and physical possibility.

Through this process, we quickly realized a profound connection between theoretical physics and art: both disciplines rely on speculation, imagination, and creativity to grapple with the unknown and the inexplicable. In that spirit, we allowed theory and speculation to become our tools for sculpting the possible timbral behaviors that sound could acquire in dark matter.

Our initial strategies involved mimicking Bertolami's theoretical process—balancing objective data and established paradigms with mental speculation about how timbre might manifest in this elusive medium. This approach, however, confronted us with the stark reality of dark matter's mystery: most, if not all, of the quantitative data available is either tangential—failing to describe the substance itself—or, in many cases, merely measurement errors (Bertolami, personal communication, January 12th, 2024).

This realization forced us to reassess our approach. By attempting to rely on objective data, we were erratically pursuing a form of sonification, rather than exploring dark matter as a mental construct. In a way, dark matter itself redirected our course, reinforcing the necessity of embracing perceptual and speculative methods rather than attempting to impose a direct acoustic representation onto an inherently intangible phenomenon.

Comparing artificial intelligence to an advanced paintbrush, suggests that AI is not a substitute for human creativity but an extension of the creator's mind. Inspired by this idea, we turned our attention to the possibility of building an AI model capable of translating mental representations into acoustic physiognomies (Agüera y Arcas 2015).

However, as Jonathan Impett writtes, "an AI is essentially a memory machine", (Impett 2023, 225) and contemporary deep learning models rely almost entirely on vast datasets to train this memory. (Dobereiner and Pirro 2024) But how do we construct a memory of something that does not yet exist? What data could be used to train an AI designed to translate a mental representation that, by definition, has no prior instance? Here, we are speaking of the primordial moment of creation—the first act, where synapses establish possible timbral behaviors in a medium where no sound has ever been heard.

Speculation, as a philosophical and artistic exercise, enables us to form hypotheses about concepts that may not be empirically verifiable, venturing into realities that exist only in inference. (Goodman 1978) It bridges imagination and experience, placing the explorative mind at the center of knowledge creation. It is the moment of world-building, where we are coloring possible sonic realities, ones that may have no counterpart in another mind or any subsequent representation under measurable standards—precisely as Fales' paradox caution.

Thus, we found no database that made sense to train, nor any meaningful outcome from such an exercise. Artificial intelligence thus proved useless for the proposed artistic experience. However, does this suggest we have stumbled into a form of artistic expression that AI has yet to grasp? Or have we not yet discovered how to make this paintbrush a true extension of the artist's mind?

4.2. The source

Philosopher Thomas Kuhn (1962) argued that when a paradigm fails to accommodate new or anomalous data, it enters a state of crisis, often leading to a complete revolution of perspectives. Faced with the limitations of AI in translating the timbral speculations, we found ourselves at such a crossroads—requiring a step back to rethink our methodological approach.

Just as a painter develops fluency with the brushes that best express his vision, it became clear that, for this installation I too would have to take on the brushes with which I express myself best. Inspired by Alvin Lucier's *I Am Sitting in a Room* (1969), a recorded spoken voice became the central element—the original sound source from which my own timbral speculations would emerge.

To that end, a text was composed from fragmented thoughts reflecting the qualitative essence of dark matter, shaped through discussions with Professor Bertolami. Structured in collaboration with theatre director and performer Ana Lídia Pereira, part of this text unfolds as a poetic narrative, navigating dark matter's dual existence—as an abstract concept and as a subject of theoretical descriptions that attempt to concretize it.

Each syllable was meticulously crafted, not for traditional musicality, but for a precise vocal performance that, like in Lucier's piece, carried the potential to make space and matter resonate at their own fundamental frequencies. This recorded voice, then, was not merely a vehicle for language but a speculative instrument—provoking mental transformations of its existence in dark matter.

4.3. Transforming the source

To transform the source within a framework of physical possibility, I followed one of Professor Bertolami's proposals, which draws an analogy between dark matter and a gas. Recognizing the impossibility of describing it quantitatively with current data, we proposed an alternative approach: writing a qualitative equation of state to contrast the behavior of sound in air versus dark matter.

$$PV=nRT$$

Equation 1. The ideal gas law where P, V and T represent pressure, volume and temperature respectively; n is the quantity of substance; and R is the ideal gas constant.

While assigning numerical values to this equation within the context of dark matter is impossible, the purpose of this exercise was comparative—juxtaposing the pressure, volume, and temperature of air in the exhibition space against the speculative properties dark matter might exhibit if it behaved like a gas.

Bearing in mind the theory that dark matter should be vastly less dense than air and that interaction between its particles is minimal, we envisioned a gigantic compression of this matter within the space. This allowed us to think of dark matter as a medium with very little density, where, from the outset, the speed of sound propagation would drop incredibly comparing to air, but it would still retain a small capacity for acoustic propagation, with pockets of greater and lesser density scattered and wandering around the exhibition space.

To represent both the wandering presence of the dark matter that shapes our world and the timbral perception that shapes our reality beneath our conscious awareness, a sculpture was created in collaboration with sculptor Helder Maia, in a black metal mesh, designed to hang and be dispersed through the space (Fig. 1.). It's an amorphous sculpture if seen in motion, its defining lines are constantly redefined by the space's wavy acoustic glass that distort it and by the position that the visitor chooses to establish—a parallel to the fluid nature of both timbre perception and dark matter, which remain elusive until framed by individual experience (Fig. 2.).

It was now my turn to mentally speculate on the timbral behaviors resulting from the passage of this voice (the source) from one medium (air) to another (dark matter). This meant painting my own mental representations of the undulatory phenomena involved in such a transition—refraction, scattering, acoustic dispersion, interference, and beyond.

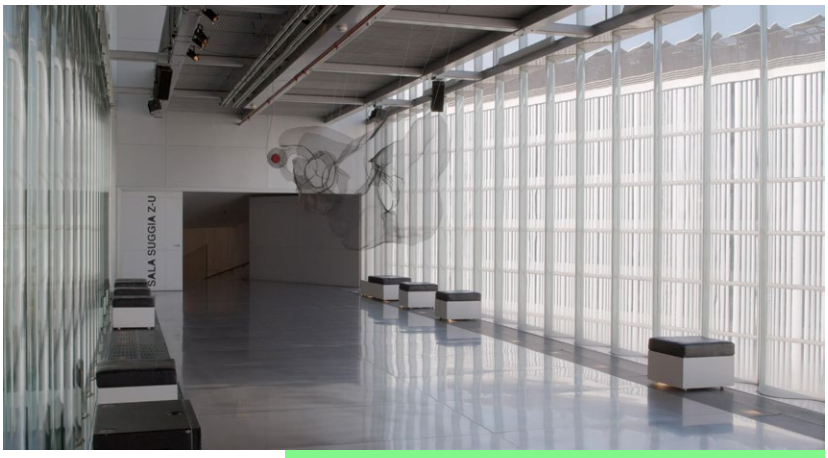


Fig. 1. *Sonic Iterations for Intangible Existences: Dark Matter* sound installation at Casa Da Música's west wing.

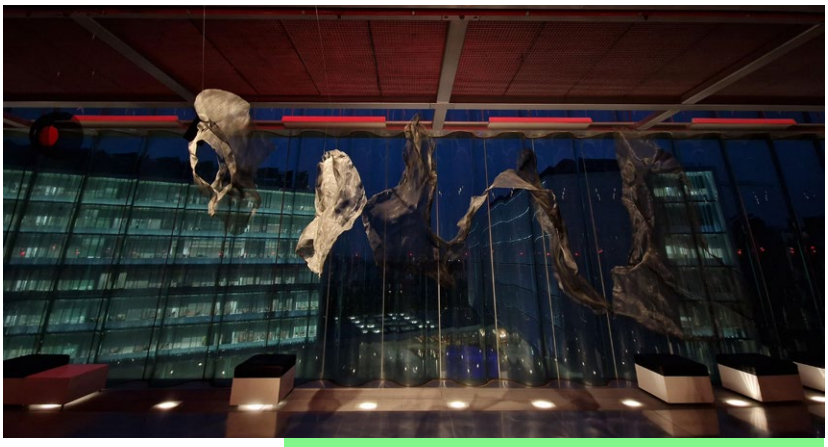


Fig. 2. Side View of the installation at night.

As electroacoustic manipulation is my most expressive brush, I turned to digital and analog tools that have accompanied me throughout my career. Through them, I sought to translate these mental representations into acoustic physiognomies, sculpting the imagined timbral transformations as precisely as possible.

To present the results of the timbral transformations without corrupting them, but at the same time be able to contextualize the visitors, it was necessary to create a bond with the original text that was being modulated. Here, Denis Smalley's (1997) concepts of Stability and Variability, central to his transformational discourse, became fundamental. Stability refers to acoustic elements that remain coherent, serving as perceptual anchors that bond the listener to the sound source, while Variability describes the elements that transform the sound, distancing the listener from identifying its origin. Smalley's framework provided a crucial method for managing the tension between these two forces—how much of the sound remains grounded in its source and how much departs into transformation.

To resolve this balance, I opted for a spatial approach. By creating two distinct sound spaces, I was able to segregate the original sound

source from its transformations, allowing for a clear contrast between stability and variability without compromising the integrity of the timbral metamorphoses.

4.4. Space A: The domain of variability

Covering the entire area surrounding the installation and extending into the west wing (Fig. 1.), Space A is dedicated to variability. Here, visitors hear only the transformed version of the original source, devoid of the acoustic cues that would reveal its origin. Timbre is liberated: It emerges purely as a construct of thought and cognition, allowing each visitor to give the sound their own version of a source, state and matter.

To enable this experience, six high-quality active tops are evenly distributed throughout the space, alongside one subwoofer on the upper floor. This spatialized acoustic design interacts with the acoustics of the room, creating the illusion that what is heard is not a playback system but an emergent response of the space itself.

4.5. Space B: The domain of Stability

In contrast, Space B serves as the point of stability within the transformational discourse. Here, the original text remains unchanged, acting as a perceptual anchor that resolves the surrounding abstract transformations. However, the text is only perceptible if the visitor precisely aligns with the red dot at the end of the sculpture. The sculpture was designed to create an optical and acoustic illusion—a single point of perspective convergence where all elements align, allowing an handcrafted ultrasonic directional speaker (Miura 2011) to transmit the unaltered text (Fig. 3.). At this point, and only at this point does the original sound become intelligible.

This creates a sonic focal point where the timbral behaviors of Spaces A and B converge into a unified transformational discourse—reminiscent of gravitational lensing, which reveals the presence of dark matter through its distortions of space-time (Fig. 3.). This configuration transforms the visitor into an active participant, navigating the tension between stability and transformation. As they move away from the focal point, the text dissolves into fragmented, diffuse, and modulated abstraction. This transition embodies Smalley's dynamic tension, where sound oscillates between recognizable form and perceptual flux.

The installation operates on eight independent audio channels, controlled via a MacBook connected to an audio interface, running a five-minute audio loop in Ableton Live 12. The timbral transformations were mapped across these channels, simulating the wandering pockets of higher and lower density, reinforcing the speculative presence of dark matter.[2]

5. Discussion: From Perception to Expression, to Perception

This installation set out to subvert traditional timbre research by redefining it not merely as a perceptual response but as an individual expression—one that externalizes the mental structures shaping auditory reality. Dark matter, as a speculative framework, proved particularly effective for this exploration. As an intangible entity, it can only be inferred rather than directly observed or heard. Consequently, the imagined timbral transformations in this installation were not influenced by external stimuli from the physical world. Instead, they emerged purely as internal perceptual events in the mind of the author.

Once these internal events where externalized as audible acoustic physiognomies, visitors navigated a space where its speculative presence was suggested through a series of timbral transformations, reinforcing the idea that the source we perceive is shaped more by individual interpretation than by its acoustic properties.

Unlike traditional timbral composition, where the acoustic result is iteratively refined between artistic intention and technical constraints, this process required a direct transposition of imagined timbral behaviors into acoustic physiognomies. However, translating mental timbral speculation into tangible sonic form revealed critical challenges. Speculation did not produce instant, fully formed mental timbral transformations, instead they evolved gradually, emerging as iterative mental exercises.

As Edwin Gordon's (2007) concept of audiation describes, the process of imagining timbral behaviors involved continuously recalling and refining previous mental versions, each iteration building upon the last. While the core character of the initial version remained intact, it gradually became richer and more complex until stabilizing at a point of perceptual resolution. This raises a key question: Could our auditory realities be no immediate perceptions but iterative constructions—where we progressively refine internal connections, generating virtual sonic versions that, as long as they remain functional, feel real to us?

Another key realization was that mental timbral representations were not governed solely by auditory perception—they also involved corporeal sensations, thus confirming an embodied understanding of timbre and suggesting a tactile dimension to Orfeus' definition of timbre as our interpretation of matter and its state as manifested through mechanical waves. To compensate for this sensory gap, a

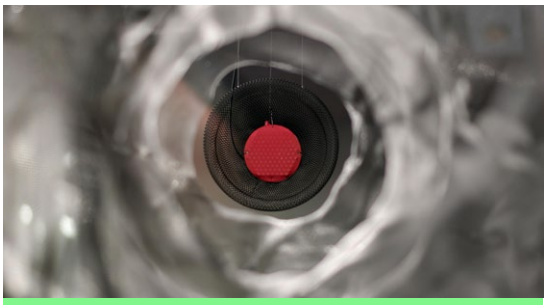


Fig. 3. Sonic focal point with a red ultrasonic directional speaker.

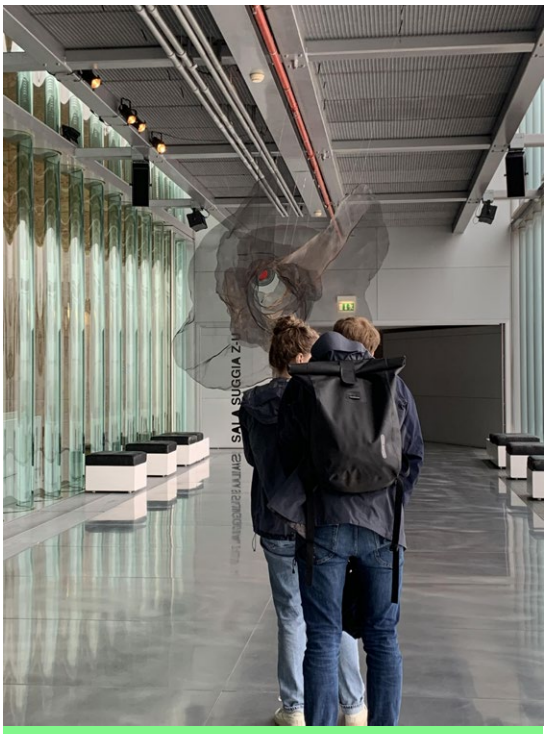


Fig. 4. Visitors listening at space B.

second subwoofer was introduced into the installation floor, reinforcing the physical impact of specific moments. Yet, even with this addition, it was not fully possible to bridge the gap between mental perception and its external acoustic representation.

Despite these challenges, the results remained remarkably faithful to the essence of the initial mental speculations. However, the final acoustic result carried an aesthetic layer seemingly inherent to the tools used. Nevertheless, in analogy with painting, the medium's constraints, do not invalidate the expression of how the artist constructs his own auditory reality.



Fig. 5. Premier at Porto Electronic Music Symposium.

5.1. The Feedback Loop

One of the most unexpected outcomes of the installation was how the segregation of the transformed sound from its original source created a perceptual effect that contradicted my own mental experience. Internally, I perceived the voice (source) and its speculative timbral transformations as a single fused entity. However, within the installation, these elements were spatially separated, allowing the source and its transformations to be heard independently. This produced a perceptual anomaly closely related to Fales' anomaly by extraction—where isolated partials, or in this case, the timbral transformations, are removed from the original sound, yet when contextualized, the source remains perceptible.

In Space A (Variability), the timbral transformations took on an entirely new dimension. Positioned at the extreme end of Smalley's transformational discourse, these sounds became detached from their material anchor (the voice), acquiring an autonomous existence. Free discussions with visitors revealed a diverse range of emotional and perceptual responses—ranging from fear and intrigue to deeply visceral reactions, including chills and other bodily sensations.

Although the installation provided no specific instructions on visitor movement, the central placement of the sculpture naturally led most visitors to first engage with the transformed timbral behaviors (Fig. 5). This revealed interesting contrasts in perception:

- Visitors that where somehow familiar with the concept of the installation, immediately perceived the timbral transformations as emanating from a voice.
- Whereas visitors with no prior knowledge of the concept, engaged with the timbral transformations as independent entities, inferring a great variety of imagined sources. However, upon encountering Space B (Stability), all these possibilities could

not escape collapsing into a single perception: the voice being transformed. This seems to validate Fales' paradox, which asserts that timbre perception is ultimately a constructed version of reality—a cognitive resolution of sonic ambiguity, it further demonstrates how external acoustic stimuli can distort or even collapse these internal realities.

- A particularly striking realization occurred when Professor Bertolami, who had never heard the piece prior to the premiere, correctly identified specific timbral transformations as representations of specific physical phenomena he had theorized, such as acoustic dispersion, weak particle interaction, and density pockets. This strongly suggests that imagined and abstract timbral cues can still evoke concrete physical phenomena, concordant across different minds when bonded by the same conceptual framework.

In Space B (Stability), the installation served its function as a perceptual convergence point, where the ultrasonic directional speaker emphasized the parallel between internal audiation and externalized sound. The highly focused ultrasonic beam, interacting with the facial bones and tissue structures, created a strange perceptual effect, making the text feel as though it were resonating inside the listener's head. This experience mirrored the author's own perception of the timbral behaviors, allowing visitors to momentarily enter his auditory reality.

6. Conclusion: Timbre as a Contingent Expression of Auditory Reality

This installation aimed to challenge the conventional study of timbre by transforming it from a perceptual phenomenon into an expressive one, much like how visual art is capable of externalizing perception. While people may agree on the identification of timbre, each individual's internal perception differs. The objective was to reveal these personal, internal constructions of timbre—showing how we individually shape auditory reality. Through artistic exploration, the work made these mental constructs tangible.

To achieve this, speculative timbral behaviors were imagined in a space where sound had never existed before—dark matter. The installation space was divided into two perceptual domains: Space A (Variability), where only the transformed timbral behaviors were heard, and Space B (Stability), where the original source was revealed through an acoustic focal point using an ultrasonic directional speaker. The presentation of these timbral speculations followed

Denis Smalley's transformational discourse, carefully manipulating the balance between stability and variability to shape the visitor's perceptual experience.

However, much like in painting, where the medium inevitably imprints its own aesthetic, this transformation did not compromise the core expression of the imagined timbres. This raises an intriguing question: Could this form of timbral expression, which exposes internal frameworks, be used to train AI as a true extension of the individual mind—externalizing mental timbre without distortion from technical constraints or aesthetic biases?

The installation also directly demonstrated Fales' timbral anomalies: in Space A, detached timbral transformations led uninformed visitors to infer multiple imagined sources, constructing virtual versions of a source to resolve auditory ambiguity. In Space B, stability and variability converged into a fusion of the original source and its timbral transformations, collapsing these virtual interpretations into a single perceptual experience—a transformed voice. This validated Fales' paradox, reinforcing that timbre perception is a constructed version of auditory reality and that external acoustic stimuli can disrupt these internal constructs.

Space B (Stability) created an uncanny auditory lens through an ultrasonic directional speaker that caused visitors to perceive the sound as originating inside their own heads. This placed the listener momentarily inside of the author's head, experiencing the fusion of source and its transformations as a single identity.

Furthermore, the act of speculating timbral behaviors in dark matter, reinforced the idea that timbre is not always determined by physical phenomena but by our interpretation of them. This was most evident in the experience of Orfeu Bertolami, who, despite never hearing the work before the premier, was able to identify specific timbral transformations as corresponding to theorized and yet unheard physical phenomena in dark matter.

This exploration is part of a broader research project that rethinks timbre and, in later stages, will seek to address some of the questions raised here. Ultimately, it invites further investigation into the possibilities of exploring timbre as a contingent expression of how each individual constructs their own sonic reality. By proposing timbre as a speculative practice, this work demonstrated that the timbral world we inhabit is not merely given—it is constructed and continually reshaped by the way we engage with the world we live in. If timbre is a reflection of our cognitive framework, how might we further explore and externalize the sonic worlds that exist within us?

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Notes

1. "Timbrar" (Portuguese) Loosely translated as "Assigning a certain characteristic to" Definition from Infopédia – Dicionários de Língua Portuguesa, Porto Editora. Available at: https://www.infopedia.pt/dicionarios/lingua-portuguesa/timbrar (*accessed February 13, 2025*).

2. An audio document of the sound installation is available upon request. Please contact the author directly via email.

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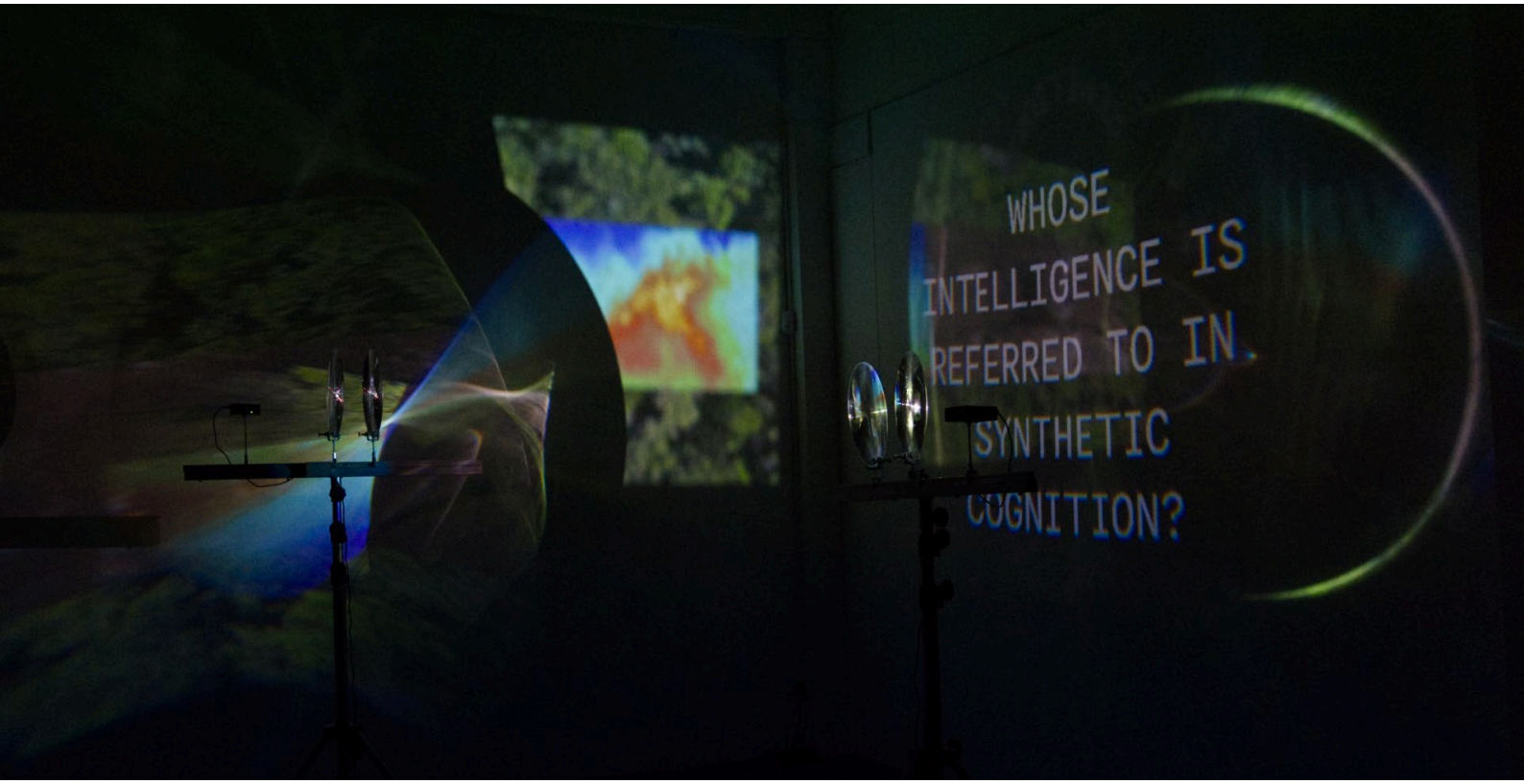
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Artworks

A Structural Plan for Imitation: Engines of Differentiation

xCoAx 2025
13th Conference on Computation, Communication, Aesthetics & X
Dundee, UK
2025.xCoAx.org



This paper presents and reflects upon the project *A Structural Plan for Imitation: Engines of Differentiation*, a sculptural video installation exploring the implications of artificial intelligence (AI). Distorting video projections through a series of fresnel lenses, the work addresses the potential for the warping of reality through machine learning (ML) systems due to an internal logic that emphasizes difference. The dispersed visuality of AI (Dvořák and Parikka 2021) has recently been explored by many artists (Zylinska 2020) and theorists (Crawford 2021) from various different angles. Not only do we have little access to the processes of interpretation that go on between the input and output of complex algorithmic systems, it's also difficult to directly represent their impacts. While projecting conceptualizations of AI as a technology of hyper-abundance – both feeding off of immense amounts of existing visual data and producing more of it – it also draws our attention to AI's overconsumption and inequitable distribution of precious resources. By drawing visual material from ML training datasets, as well as documentation about their material infrastructure, the project reflects on difficulties in articulating the expansive scale on which these systems function.

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Introduction

A Structural Plan for Imitation: Engines of Differentiation is a sculptural video installation where warped visualizations reflect on similar processes that occur through machine interpretation in artificial intelligence (AI). The project questions how value systems embedded in AI systems lend themselves to the cultivation of difference, from the logic of mathematically discerning one from other using machine learning (ML) to the large-scale societal implications of applying such statistical models to the world. In this two-channel video installation, digital projections exploring the hyper-visuality of AI imagery are distorted through a series of fresnel lenses. Applying strategies of *détournement* (Debord and Wolman 1956) to the images behind the images, and machine learning training datasets, the piece brings viewers into the complex relationships AI creates between the visual and nonvisual, data and images. Re-appropriating images from ML training datasets and considering them more closely as well as visually distorting them seeks to explore the layers of interpretation, re-interpretation, and, potentially, misinterpretation that occur within AI systems.

Background

The growing prevalence of computational media (Carvalhais 2022) has reshaped visual culture in ways that many artists, theorists, engineers, and the public have struggled to make sense of (Zylinska 2020; Dvořák and Parikka 2021; Crawford 2021). Within this shift, new technical capacities of generative AI systems confront us with so much visual data that it's beyond our human capacity to look at it all. Not only have ML systems consumed virtually the entire contents of the existing internet, but they also increasingly run on amassed generated content, often filled with bias and errors (Bender et al. 2021). The use of AI to create images also entails highly problematic issues on many levels, from procurement to labelling, analysis, and recirculation of visual data, often with little regard for the ethical impact the technology may have. As Matteo Pasquinelli points out, AI as we know it now emerged out of the aim to "mechanise the mental labour of clerks rather than the old alchemic dream of building thinking automata" (2023, 52). With this in mind, not only can we not take the claims of technology corporations at face value, but we are reminded that often the same applies to the forms of media that are implicated in the deployment of AI. The project seeks to bring viewers into that conversation by presenting them with visual data from various stages of processing through ML, accompanied by text and audio discussing the complexity of this topic.



Fig. 1. Installation view. Photo: Nikos Avraamides, 2024.

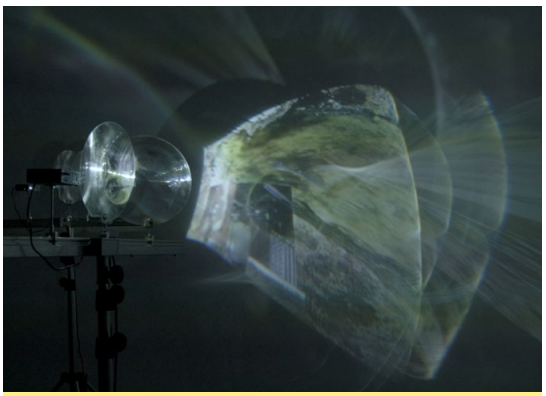


Fig. 2. Installation view. Photo: Nikos Avraamides, 2024.



Fig. 3. Detail view of projection through lenses. Photo: Nikos Avraamides, 2024.

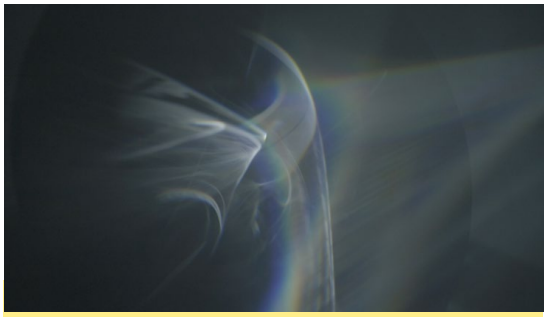


Fig. 4. Detail view of distorted projection. Photo: Nikos Avraamides, 2024.

Installation

In this work, a flood of visual information is fed through apparatuses that enlarge and distort what viewers see within the surrounding space. At various times, one can make out glimpses of coherent images: faces from biometric imaging databases; ordinary objects and animals; aerial surveillance footage – the likes of which are used to train many computer vision systems. These are combined with images situating artificial intelligence, historically and materially, drawing from the prehistory of artificial intelligence – when supercomputers were needed to process even simple inputs and long before the idea of computers creating realistic, photographic images became commonplace – as well as documenting its resource-intensiveness: devouring not only data but also energy and precious minerals.



Fig. 5. Video documentation of the work.

In the accompanying narration in the work, a voiceover addresses the circularity of this topic: how foundational aspects of the technology may make it difficult or even impossible to subvert its divisive tendencies. For example, in certain respects, generated visual media defies prior conceptualizations and calls for new perspectives to address its intricacies, but this requires a familiarity with the history of algorithmic media (Lee 2024) to inform approaches that meaningfully depart from the past.

Rather than attempting to present a coherent position on the topic of AI imagery, this work explores the numerous perspectives and issues that converge in its complex processes and surrounding discourses, including its capacity for self-contradiction. In this respect, the project drew inspiration from Raoul Vaneigem's statement that "there is no weapon of your individual will which, once appropriated by others, does not turn against you" (1967, 9). This idea, informed by the situationist approach of *détournement* highlights both the difficulty of attempting to find ethical inroads into this topic, as well as offering an opening to subvert AI's potentially harmful aspects to turn the technology against itself. By reversing our view of the technology, we may gain a better understanding of ways forward that are informed – rather than hindered – by its vulnerabilities.

Conclusion

As we struggle to come to terms with artificial intelligence's affordances and perils, it is especially relevant to consider to what extent these methods and their outputs may entail nuances that distort the reality at hand. *A Structural Plan for Imitation: Engines of Differentiation* enquires into discrepancies between the promises made about artificial intelligence and the realities of how it materially acts on the world by

looking into what lies below the surface of generated images. With the current emphasis on methodologies that rely heavily on ML models, it's crucial to examine the assumptions, power dynamics, and ideologies embedded in AI systems and how they may distort perspectives on many aspects of this topic. The project delves into this idea by looking closely at models' structuring of relationships between visual perception, real-world phenomena, and the traditional systems of value that have culminated in the present pervasiveness of artificial intelligence.

Project page:
emare.eu/works/a-structural-plan-for-imitation-2024

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An Atlas to Track Blockchain Colonialism

xCoAx 2025
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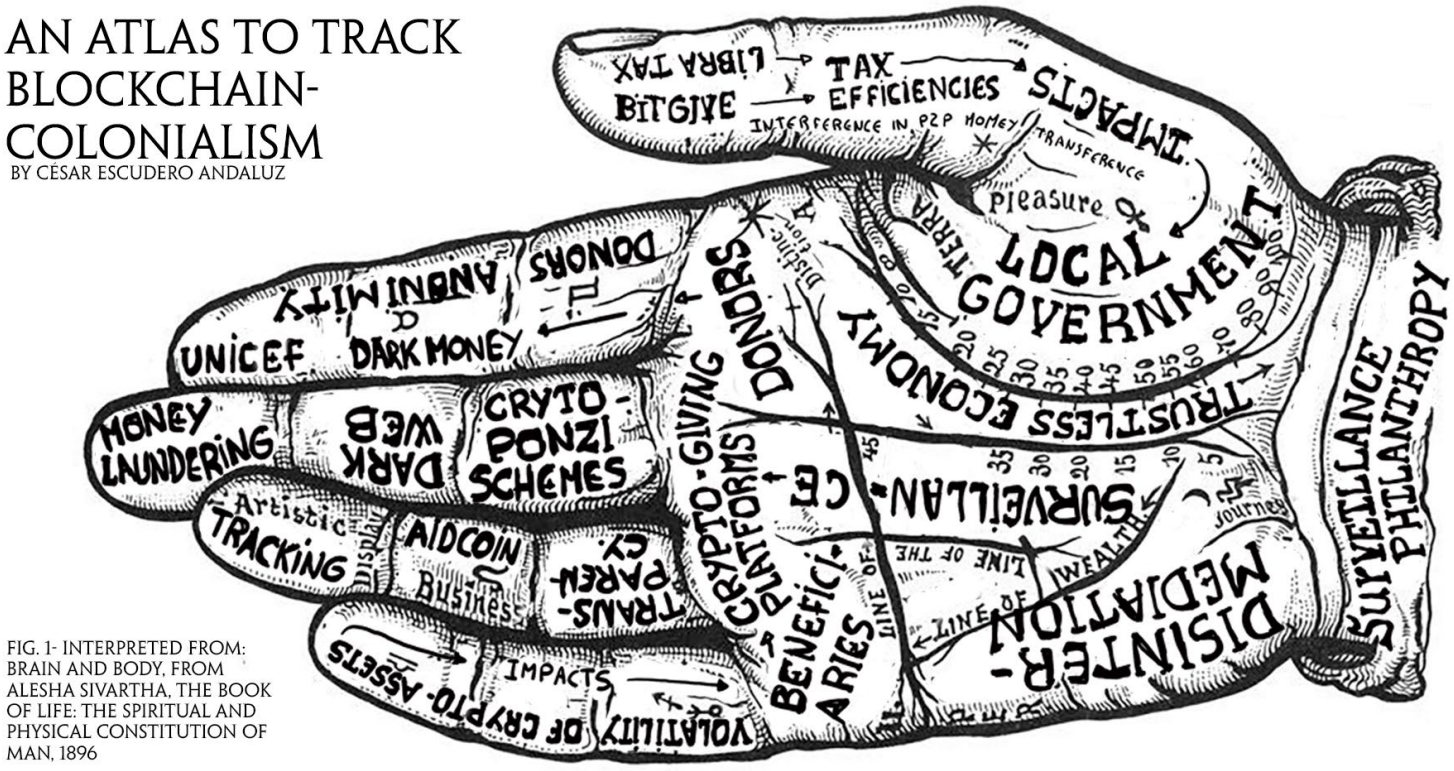


FIG. 1- INTERPRETED FROM: BRAIN AND BODY, FROM ALESHA SIVARTHA, THE BOOK OF LIFE: THE SPIRITUAL AND PHYSICAL CONSTITUTION OF MAN, 1896

To understand Blockchain Colonialism, we must go beyond cryptocurrency investments, NFTs, and metaverses to bring the user closer to a more objective reality. To create an image of it, we need to investigate the relationships between planetary resources, human labor, economics, surveillance, and privacy. In this relationship, platforms, infrastructures, devices, corporations, governments, and individuals create a complex picture that is difficult to visualize with integrity. The objective of this atlas is to monitor how individuals, corporations, and governments have used blockchain to cross borders and extract benefits from those most in need, including land, labor, data, privacy, and other resources. Authors such as Mirka Madianou, Kate Crawford, Vladan Joel, Inte Gloerich, Oliver Jutel, and Peter Howson help us to understand the colonial and extractive legacies, the promises of economic and governance alternatives imposed on fragile societies in the developing world.

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Keywords: Blockchain Colonialism, Cartography, Robbery, Crypto-Evangelists, Tokenization, Extractivism, Ngos, Refugees

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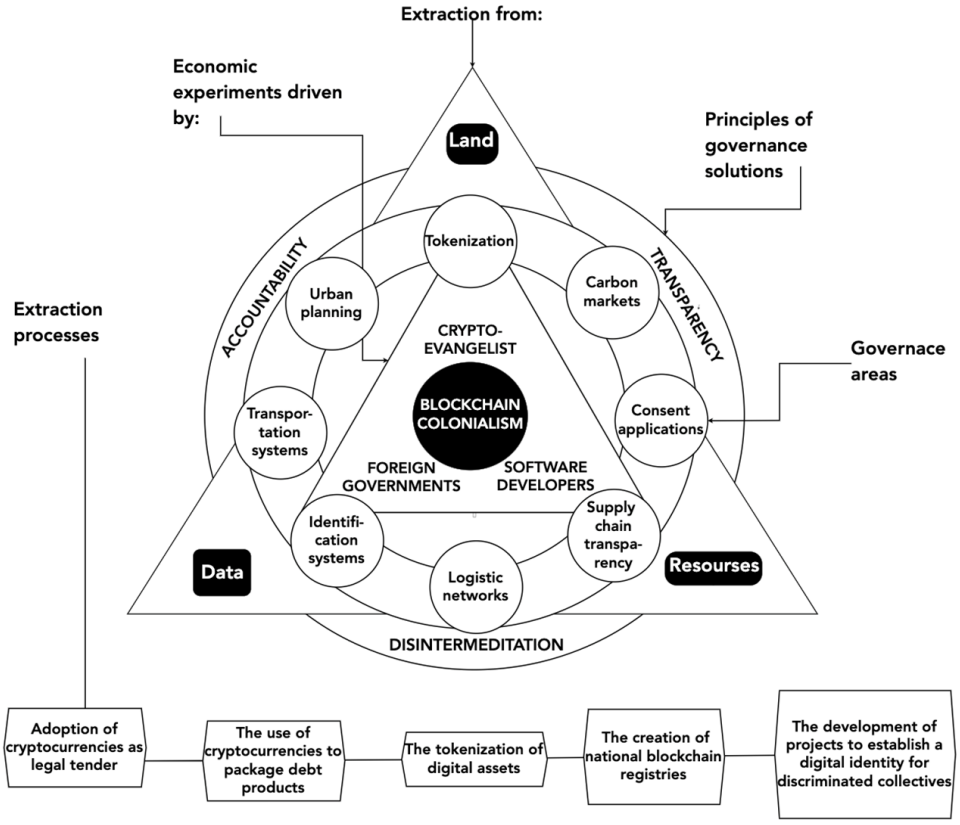


Fig. 1. Blockchain Colonialism 2024 Diagram.

Deconstructing blockchain rhetoric

The false promise of blockchain lies in its claims of universality, which go beyond a platform that mediates data and provides services in the cloud; in the humanistic sector, blockchain aspires to influence governance systems for data production and platform dependency. In doing so, it establishes a technological frontier, where the valuable resources of the developing world become objects of paramount importance (Jutel 2021). Moreover, blockchain behaves as a substitute for trust between people; it promises to democratize big data, offering all kinds of governance solutions under principles such as transparency, disintermediation, accountability, and efficiency (Jutel 2021).

Blockchain Colonialism

Blockchain colonialism encompasses economic experiments driven by foreign governments, software developers, and crypto evangelists, who have used encryption, security, and trust emblems to extract benefits from those most in need. This situation has been possible through different processes such as adopting cryptocurrencies as legal tender, creating national blockchain registries, using cryptocurrencies to package debt products, tokenizing digital assets, or developing projects to establish a digital identity for discriminated collectives (Howson 2021). In addition, these processes have been combined with social governance systems in areas considered underdeveloped from a Western

perspective, such as supply chain transparency, consent applications, logistics networks, identification and transportation systems, urban planning, and carbon market tokenization.

Silicon Valley's solutionism

Silicon Valley's solutionist innovation, performative entrepreneurship, and hackathons have blurred the boundaries between NGOs and platform developers that have combined extractive practices with Internet-connected computer quantification methods to analyze data and turn them into predictive products, justifying some of these practices in the context of "emergencies." Where artificial intelligence (AI) is used, among other things, to track displaced people and predict population flows. Consequently, blockchain colonialism creates risks for non-profit organizations such as WWF, Oxfam, and UNICEF (Howson 2021).

Obscurantist paradigm

In addition, in vulnerable communities such as refugees, climate migrants, or local communities, blockchain projects impose and force them to give up personal data in exchange for basic needs, which can lead to unpredictable capitalization in the future (Gloerich 2023). According to the researcher Peter Howson, this data could also be used to make decisions about individuals, with far-reaching consequences (Howson 2020). For example, the US state could ration resources or determine migration rights by combining biometric data, reputational evidence, and social network data secured on the blockchain (Jutel 2021). Furthermore, the media professor at Goldsmiths University, Mirca Madianou, argues that states and governments increasingly use biometrics to control borders and keep out "undesirable" populations (Madianou 2021).

This is possible regarding technical infrastructure through mobile applications, smart contracts, and the web3 operated through engineered protocols. This means that they cannot work outside the way they are coded. Consequently, programmers and corporations have greater agency. According to Oliver Jutel, algorithmic governance and pure mediation claims make this technology obscurantist and difficult to disentangle from rhetoric and ideology (Jutel 2022). Another clear example is Worldcoin, a startup created by OpenAI CEO Sam Altman in 2019, which uses orbs to scan people's eyes in exchange for a digital identity card and cryptocurrencies.

Counter-actions

To find a more coherent way forward, Inte Gloerich argues that it is essential to create alternative spaces that challenge and resist dominant logics of exploitation to envision ways to undermine, resist, de-center, or subvert the current situation, shedding light on the intersection of decolonial thinking, blockchain technology, and artistic practices (Gloerich 2023). On the other hand, Julian Crandall stresses that blockchain technology can be constructively applied through democratic participation and anti-colonial struggles and that it is essential that local developers participate in these blockchain initiatives rather than relying on outsiders (Crandall 2019).

Crypto-giving

Donating and transmitting traceable digital assets through platforms such as BitGive can be more tax-efficient than selling them. Some intermediaries, such as LibraTax, offer advisory services that enable donors to transmit digital assets with the lowest possible tax burden. These services displace undue and corrupt state interference in money transfers in the relationship between donors and beneficiaries. This framing of the state as a corrupt entity in the Global South has meant that many poorer countries are not raising enough tax revenue to fund even the most basic services, such as health and education. As the UK Tax Dialogue reports, “if we are to achieve the ambitious Sustainable Development Goals (SDGs), cryptocurrency platforms are ultimately an impediment to achieving those goals” (Howson 2021).

Other fields of action used to justify crypto-colonialism are more related to transnational approaches and sustainable development, such as biodiversity conservation, climate change adaptation and mitigation, and managing carbon offsets. For example, projects like Nemus.earth and Moss.earth tokenized parts of the Amazon rainforest to sell as NFTs. These projects continue the economy of rarity established by collectible NFTs, where unique features increase land value and are governed by stakeholders in a DAO (Gloerich 2023). However, as in historical colonialism, these symbolic representations are abstract assets that promise future income and care little for the survival of what they represent (Juárez 2021).

Critical contextualisation and self-reflexive discussion of the artwork

Developing maps, data visualisations, and diagrams is a process of knowledge creation rather than knowledge revelation (Dodge 2000).

Over the last few years, many artists, including Suzanne Treister, Mark Lombardi, Bureau d'Etudes, ShareLab, Übermorgen, Paolo Cirio, and RYBN have been working with diagrams as a tactic to unmask hidden dominant narratives of the world, helping to understand complex power structures, and bringing the audience closer to a deep research project based on vast amounts of information. The researcher Kate Crawford introduced the atlas as a method to make information more accessible in her book *Atlas of AI* (2021), and together with Vladan Joler, they created the diagram *Anatomy of AI System* (2018) to understand the real costs of large-scale AI systems.

My previous artistic practice has also used visualization as a methodology. In collaboration with Martín Nadal, we developed *Bittercoin, the worst miner ever* (2016) to visualize the waste of energy and resources of the Bitcoin Miner Industry. Also, the diagram E*conomy, knowledge and Surveillance in the age of Cryptocene* (2018). Doing an analogy between knowledge privatization and the accumulation of information in the networked world. *An Atlas to Track Blockchain Colonialism* takes this previous experience to ground the critique of this technology, in an analog format outside of Blockchain.

Project page:
https://escuderoandaluz.com/2024/04/10/an-atlas-to-track-blockchain-colonialism/

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Do Not Drop (Parcel Series)

xCoAx 2025
13th Conference on Computation,
Communication, Aesthetics & X
Dundee, UK

2025.xCoAx.org



A medium-sized package departs from the artist's studio in Vienna, traveling to Dundee, where it is received at the exhibition venue. This everyday logistical process becomes the core of Julian Palacz's investigation. Equipped with a hidden camera, microphone, GPS tracker, and motion sensors, the package autonomously gathers data throughout its journey, revealing the otherwise invisible transit spaces and logistical infrastructures that govern global commerce. Palacz's work offers an unfiltered view into expansive, nearly deserted halls, where automation dictates the movement of countless parcels, efficiently coded, scanned, and redirected. His installation dissects this mechanized choreography, questioning the role of human agency in an increasingly automated system. By transforming collected data into a multimedia installation – including video, sound, and plotted movement records – Palacz makes tangible the hidden spaces and rhythms of modern logistics. The work raises questions about efficiency, anonymity, and the materiality of digital exchange, offering a rare glimpse into the infrastructure that underpins contemporary consumption.

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Keywords Logistics, Parcels, Shipping Industry, Sousveillance

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Introduction

A medium-sized package, inconspicuous in its exterior, embarks on a journey. From Vienna, it makes its way through an intricate network of distribution centers, conveyor belts, and sorting facilities, before reaching its final destination. Yet, unlike any other package, this one does more than just travel – it observes, records, and exposes the hidden spaces of global logistics.

Julian Palacz's *Parcel Series* is an artistic intervention into the vast and largely invisible infrastructure of contemporary commerce. Through the package's built-in sensors – camera, microphone, GPS tracker, and motion detectors – Palacz captures the rhythms and structures of logistics: endless halls, automated scanning processes, and the seamless, yet eerie choreography of goods moving through depersonalized distribution centers.

The Logistics of Visibility

The rise of e-commerce has radically reshaped supply chains, with record-breaking volumes of parcels being transported worldwide. In Austria alone, annual shipments have surged from 50 million a decade ago to over 165 million today. Despite the scale and complexity of these operations, our understanding of how they function is minimal. Palacz's work sheds light on these hidden processes, making the unseen visible.

With his package as a passive observer, we gain access to near-empty warehouses the size of multiple football fields, designed solely for maximum efficiency. Packages glide along conveyor belts, sorted and directed through a finely tuned system that minimizes human intervention. Here, the human role is reduced to the final step – the so-called "last mile" – where precariously employed couriers shoulder the responsibility of ensuring delivery, often becoming the sole visible actors in an otherwise automated chain.

Materializing Data

Beyond video documentation, Palacz transforms the collected data into tangible forms. One key element of the exhibition is a plotted seismographic record of the package's journey – an analog visualization of its physical encounters along the way. Every vibration, impact, and directional shift is transcribed onto a long paper roll, revealing the otherwise imperceptible movements the package endured. By giving form to this ephemeral data, Palacz bridges the gap between digital abstraction and physical reality, challenging the notion that logistics exist purely in the realm of the immaterial.

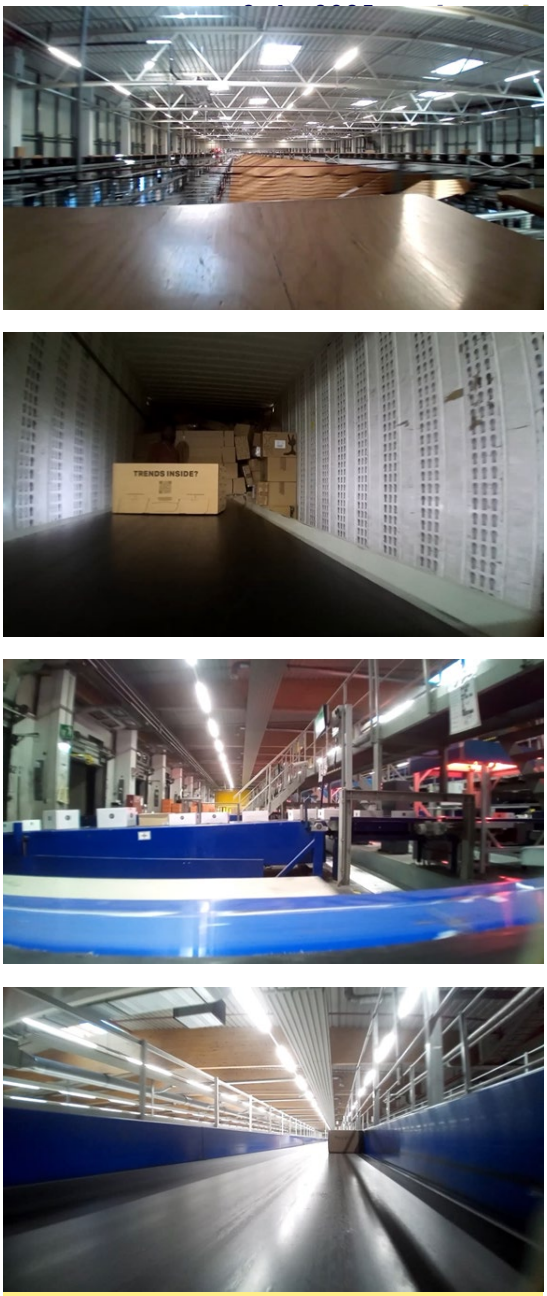


Fig. 1. Video Stills *This Side Up*, Bildraum 07, 2022.

This interplay between data and materiality underscores a broader tension: while digital infrastructures promise seamless connectivity, their operations are deeply physical. Vast spaces, precise coordination, and intricate logistics networks underpin our daily transactions, yet they remain largely outside our field of vision. The project not only exposes these structures but also invites us to reconsider our role within them. Are we mere spectators of this automated spectacle, or do we bear responsibility for the systems we continuously reinforce through our consumption habits?

In a world where digital transactions mediate our relationships with material goods, Palacz's project disrupts the illusion of frictionless exchange. The journey of a single package becomes a case study in the mechanics of contemporary mobility, revealing the labor, infrastructure, and decision-making processes that remain obscured behind the veil of convenience.

By monumentalizing the aesthetic of logistics, Palacz's *Parcel Series* challenges us to look beyond the package at our doorstep. It compels us to acknowledge the spaces and mechanisms that make such deliveries possible and to question the consequences of a system where efficiency trumps human presence. In doing so, Palacz offers not just a critique, but a moment of revelation – one that urges us to reconsider the invisible yet omnipresent networks shaping our world.



Fig. 2. *Handle With Care* video installation, Forum Stadtpark, Graz, 2021.



Fig. 3. Custom shipping labels with algorithmic haikus, Bildraum 07, 2022.



Fig. 4. Vibration (acceleration) protocol, *This Side Up*, Bildraum 07, 2022.



Fig. 5. Vibration (acceleration) protocol (detail), *This Side Up*, Bildraum 07, 2022.



Fig. 6. Vibration (acceleration) protocol, *Handle with Care*, Forum Stadtpark, 2021.

Further information on the series:

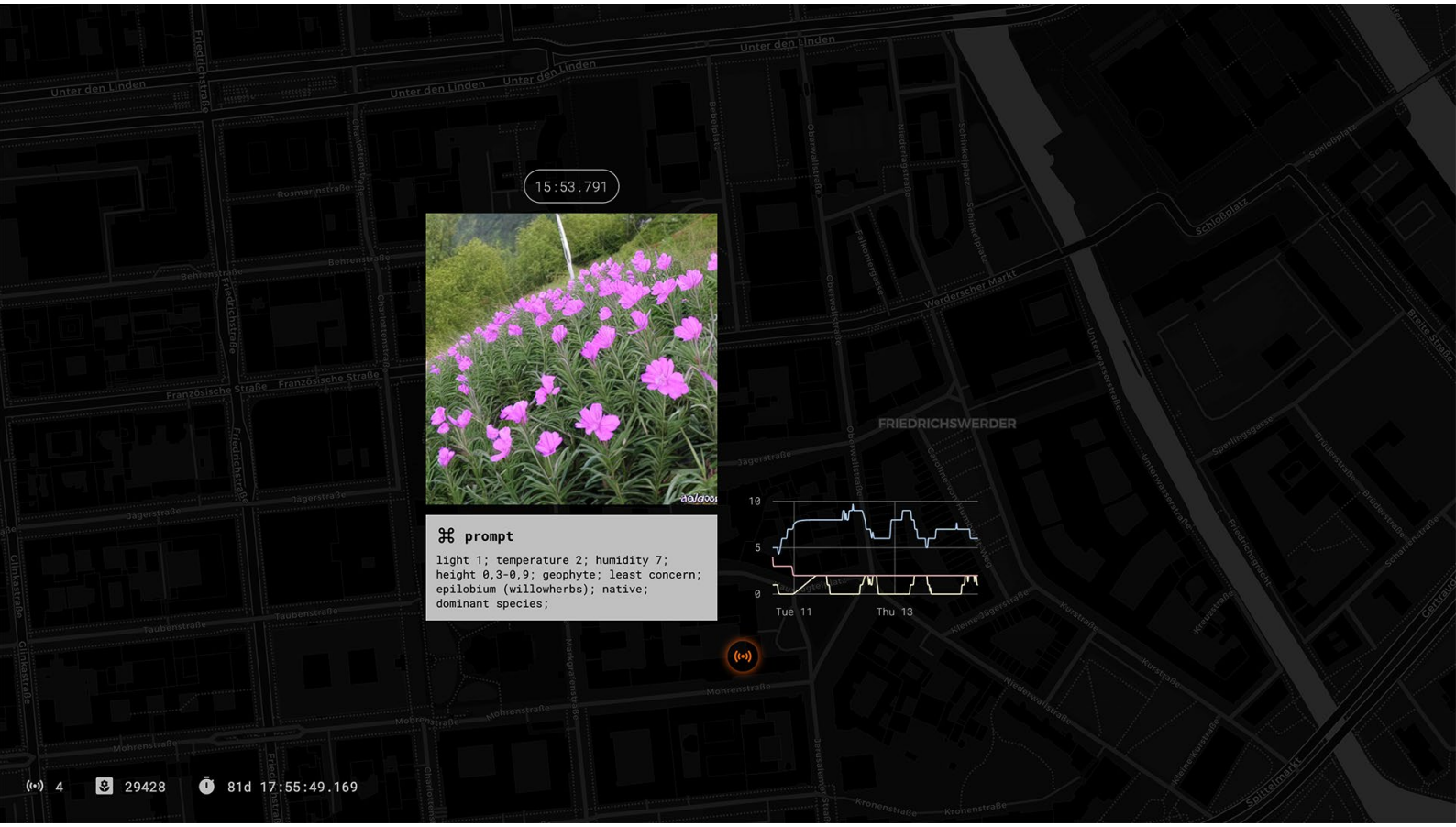
https://julian.palacz.at/handle-with-care/

https://julian.palacz.at/this-side-up/

Garden Me Tender

xCoAx 2025
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Garden Me Tender is an ongoing project that investigates the legal concept of agency, questioning whether vegetation could acquire land ownership. Data collected from residual plots is linked to an AI model retrained on the Czech flora and vegetation database, generating speculative images of plants that *could* grow under specific conditions. By merging legal institutes, technology, and artistic practice, the project reframes ownership beyond human-centered constructs, prompting reflections on the role of emerging technologies in redefining agency, subjectivity, and the rights of nature in an increasingly *datafied* world. At xCoAx 2025, we would like to develop the third iteration of *Garden Me Tender*, focusing on collecting ecological factors by positioning sensors near the location in Dundee where the conference will take place. The exhibition will consist of displaying images generated by artificial intelligence (Stable Diffusion) based on the data collected by the sensors.

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Keywords Postnature, Agency, Legal Subjectivity, Sensing Practices, Diffusion Model, Machine Learning

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The Case

The project *Garden Me Tender* continues a research trajectory that began around 2020, as a way of exploring the recent phenomenon of granting legal personhood to natural entities. The first prototypical version of the project took shape in May 2024 with the creation of a case study *Parcel No. 981*, starting from the vegetation that had colonized the remains of an abandoned factory.

This specific site, located at the foot of Špilberk Hill in Brno, is raising key questions about its shifting ontological status over time. Originally built around 1892, the factory had been partially excavated into the hillside, as evidenced by a section of embedded rock in the basement. Over time, vegetation had grown on the rear section of the factory, which had fallen into disuse. The factory walls, which bordered other residential structures along Pekařská Street (formerly Bäckergasse, a suburban district of Brno dating back to the High Middle Ages), now enclosed this new growth. The architectural composition of the site evoked images of a *hortus conclusus* – medieval monastic gardens. Yet here, the monastery and its cultivated flora had been replaced by city infrastructure and ruderal species. This new vegetal assemblage emerged as an adaptation to shifting environmental conditions and to the specific mineral composition of the soil.

Floristic research from the 1970s by botanist František Grüll (1979) focused on sites constantly exposed to human intervention, such as former quarries, railways, and post-industrial sites, where vegetation was shaped by anthropogenic disturbances. These areas, defined as habitats for synanthropic flora, often became refuges for threatened plants displaced by agricultural land use or for newly introduced species, such as those brought into the country via imported wool. These sites, also referred to as “vague terrain” (Haluzík 2020), “*délaissé*” (Clément 2005), or simply categorized as “other areas” in cadastral registries, are typically not considered ecologically relevant, unless a protected or endangered species of bird or fungus is found there. In such cases, this might interrupt their temporal suspension by assigning them a use or function within the urban productive machine.

Is it possible to define such sites on the basis of their environmental specificities or by the relations and multiple agencies at work? What role does emerging plant communities play within the discourse on the recognition of legal personhood for natural entities? How might synanthropic flora enhance the perceptibility of non-human forms of agency?

The vegetation, by reclaiming the minerals embedded in the bricks – without which it could not exist – seemed to be becoming something



Fig. 1. *Parcel No. 981*. Photo: Denisa Römerová, 2024.

distinct from both the hill and the factory, while at the same time remaining part of them. This led to an investigation into the possibility of recognizing the *de facto* power exercise over time by vegetation on the (abstract) parcel. Collaborating with Professor Lososová (2024) from the Department of Botany in Brno, we identified various types of spontaneous plants – some native, others neophytes, most likely introduced by birds or ants. The mapping reveals a landscape still undergoing transformation, composed of plants with a competitive ecological strategy – species that thrive in habitats with sufficient resources, non-extreme conditions, and limited disturbance. It is assumed that these conditions have existed in the parcel for approximately 50 years.

This long-standing vegetal presence evoked the legal concept of adverse possession (*usucapio*), a principle by which ownership is acquired through long-term, peaceful, and uninterrupted possession. Despite fulfilling these criteria, plant communities – lacking legal personhood – cannot claim land. And yet, their prolonged and undeniable occupation invites a speculative rethinking of such frameworks: could land be claimed by more-than-human forces, simply by virtue of persistent presence?

Sensitive Practices

> Posthuman subjects are formative processes resulting in dynamic structures, affectively embedded within wider complex systems comprising inter-cultural, multi-species nature-culture continuums. (Bignall 2022)

Today, the concept of agency has undergone profound re-evaluation compared to its original humanistic conception, which was grounded in intentionality, rationality, and voice, and tied to a reductive view

of subjectivity. In posthuman and new materialist thought, a broader, more relational perspective has emerged – one capable of including the multiple non-human actants with whom we co-inhabit and co-constitute our shared world. The Anthropocene, as Jeffrey Scott Marchand notes in the *Posthuman Glossary* (2018), compels us to recognize and take seriously non-human agencies as active and affective forces participating in world-making – laying the groundwork for new ethical parameters to guide future actions. In this scenario, we must ask: what does it mean today to act, to intervene, and to produce effects – sometimes unpredictable – within a living, more-than-human web of material relations?

A recent study on Brno's spontaneous flora documented 1,492 taxa present in the area between 2011 and 2021. Led by Professor Lososová (2024), the research aimed to highlight the ecological significance of urban vegetation. Using a grid-based methodology typically applied to protected areas, the study proposed that urban spaces, too, be considered potential centers of biodiversity. It drew a strong correlation between land use and floristic diversity, classifying seven categories of land use (residential, industrial, urban, agricultural, forest, meadow, and aquatic) to analyze how abiotic conditions influence the distribution and survival of plant species in the city.

Abiotic factors – nonliving physical and chemical aspects of ecosystems, such as sunlight levels, soil chemistry, and climate – shape the environment. Each plant species responds to a combination of these parameters, such as light availability, temperature, continentality, humidity, soil acidity, and nutrient richness. These plant preferences were systematically recorded through extensive fieldwork by the German ecologist Heinz Ellenberg and compiled into what are now known as the Ellenberg indicator values. These values remain a widely adopted tool in contemporary botanical and ecological research, offering insight into the environmental tolerances and habitat preferences of plant species.

The idea that abiotic conditions determine the survival of certain plant species and/or the transformation of entire plant communities recalled the notion of "vibrant matter" (Bennett 2010) and brought to mind the thermostat – a common domestic device used to detect and display temperature fluctuations. What kind of knowledge could this tool offer when recontextualized from a domestic to an outdoor place, detecting environmental factors that shape plant communities?

Responding to these questions, sensitive environmental sensors – capable of measuring light, temperature, and humidity – were in-



Fig. 2. *Garden Me Tender* sensor. Photo: Polina Davydenko, 2024.

stalled on *Parcel No. 981*. These DIY, energy-autonomous devices detect and store fluctuations in electromagnetic fields, converting them into numerical values visualized as time series. Connected via wireless signal to a server, each data point is time-stamped and associated with a unique identifier.

While data collection is often linked to surveillance and control, here it is reconfigured as a form of testimony – a way for the vegetation to demonstrate its uninterrupted, long-term presence. Since Galileo, data collection has been foundational to scientific inquiry – a core method for exploring and instrumentalizing the world. Yet data only becomes "objective" under specific epistemic conditions; the knowledge extracted through data is never neutral – it is an active force shaping and manipulating reality (Javůrek 2019). The term *data harvesting* – used by AI scholar Kate Crawford (2021) to describe the planetary-scale extractivism of Big Tech – evokes both the literal mechanics and the allegorical consequences of this practice. In this project, however, measurement becomes a performative act that seeks to return agency to nature – affirming its own spatial logic and autonomy. Within this context, abiotic conditions emerge as the only true *nomos* – the regulating principle – for every individual plant.

Proof as Evidence as Proof

As is written in contribution to *More PostHuman Glossary*, under the gloss "Ecolaw": "We inhabit a nomos", so "the law is the product of ecologically-connected legal subjects that coalesce into normative worlds" (Davies 2022). These worlds from socio-legal theory are situated in the everyday routines and relationships of social life. Posthuman discourse positions itself as a valuable tool for reimagining law; however, the shadow of the legal subject and of agency in the strict sense – both tied to intention and will – still persists. Is this

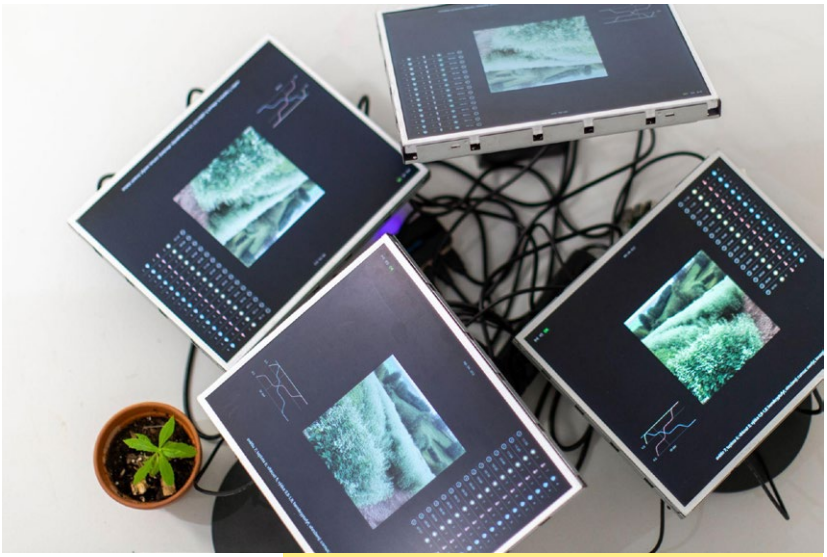


Fig. 3. *Garden Me Tender* installation. Photo: Barbora Trnková, 2024.

concept of legal agency, tied to persons, still valid when applied to plants – beings that are inherently collective and vitally dependent on 'weaker' forms of agency? Could the collected data on abiotic factors – once contextualized and made visible – serve as evidence of the legal subjectivity of the parcel, or do they instead reveal the fictional construction of both the subject and the parcel?

Data visualization became another key element. The environmental data collected by the sensors was not only plotted as diagrams or time series, but also transformed into images. These images, speculative in nature, represent fictitious plants: visual metaphors for organisms that could potentially survive under the recorded abiotic conditions. This was made possible by integrating the data with a retrained instance of Stable Diffusion – an image-generation model fine-tuned on the Czech flora database (*pladias.cz*). Hosted on the same server as the sensor data and accessible via an API, the model receives environmental prompts in the form of Ellenberg ecological indicators. When queried by a microcomputer running a display application, it generates an image of a hypothetical plant suited to the previously gathered conditions. The app periodically collects raw values from the server, reformulates them into ecological indicators, and displays both the data and the generated image of the hypothetical plant.

Geographic maps are no longer the sole tools of neocolonial power. Today, colonization is encoded in charts, diagrams, n-grams, and vectors – the fluid, persuasive aesthetic of data visualization that conceals systems of extraction and control (Pasquinelli and Joler 2020). Knowledge itself has become a territory to conquer, its flows diverted by algorithms, its truths flattened into readable conquest. Against this, our project enacts a *détournement*: we repurpose these very techniques, distorting their logic to amplify non-human agencies and restore abiotic sovereignty. We invoke the speculative legal notion of

usucapio not to justify possession, but to imagine a counter-claim: what if plants, rocks, or atmospheres, by resisting, could reclaim space from human systems of domination? In doing so, we challenge not only human centrality, but also the legal and epistemic architectures that have rendered the world a resource to be harvested.

Notes

Website:
https://gardenmetender.site

1. As discussed by Grüll (1979) in Czech, in Synanthropic flora and its distribution in the city of Brno.

2. These notions are discussed, respectively, by Haluzík (2020), in Czech, in City Upside Down: Vague Terrain, Inner Peripheries, and Places Between Places, and by Clément (2005) in Manifesto of the Third Landscape.

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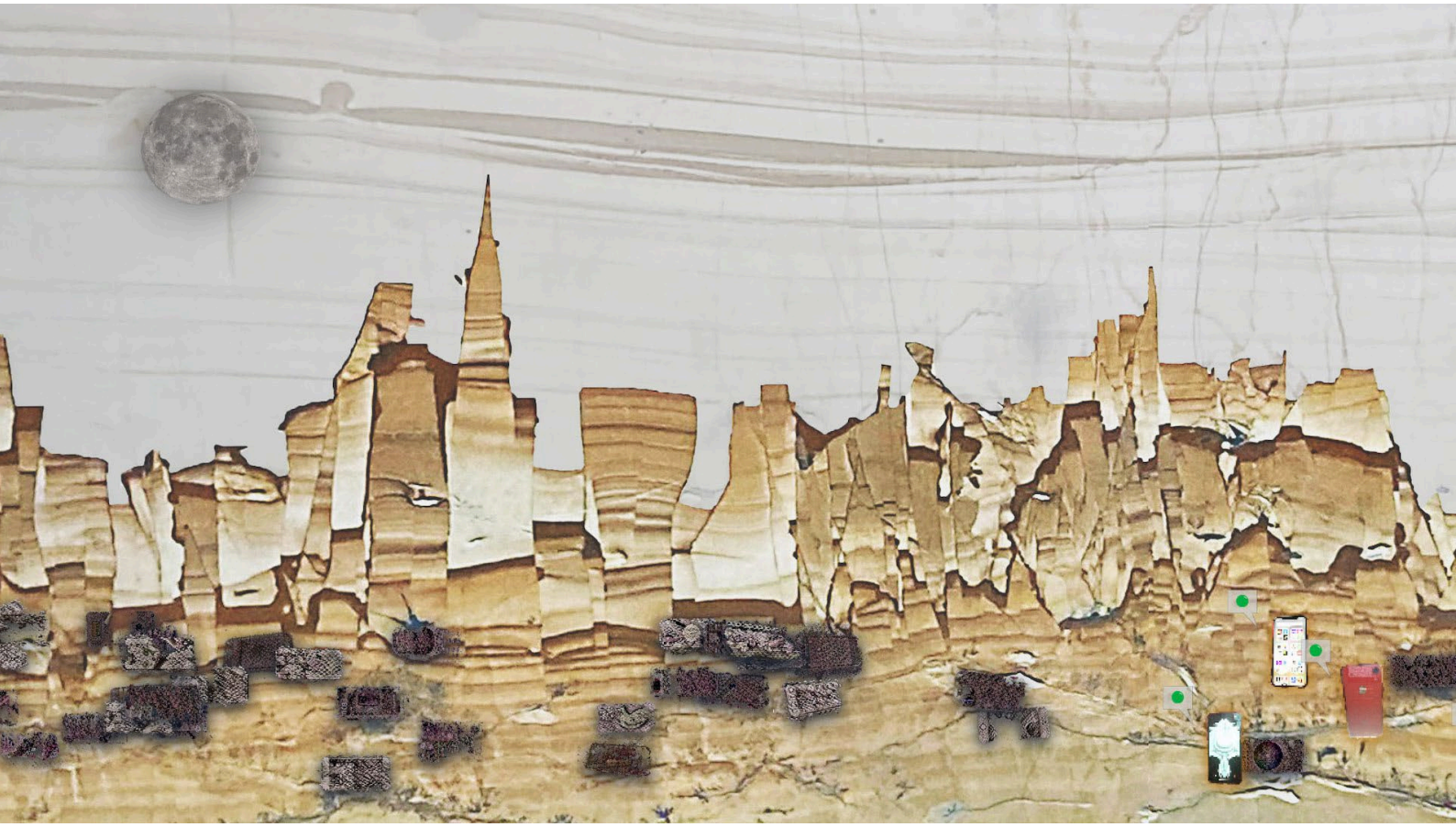
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Lives of Your Smartphones

xCoAx 2025
13th Conference on Computation,
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Dundee, UK
2025.xCoAx.org



This paper describes the approaches and outcomes of the author's critical digital art project, *Lives of Your Smartphones* with relevant contextualisation. The project provides a web-based participatory photo collage and displays and accumulates photographs of smartphone handsets submitted by the public. The work makes visible the materiality of digital technology, in particular smartphones and the environmental degradation associated with them concerning geological materiality, e-waste, airborne pollution and planned obsolescence. The practice of the project mobilises the notion and operation of decay to make visible the environmental degradation associated with digital technology through art-led experimental innovation of digital images and programmes. This practice of decay acts as a counternarrative of the techno-capitalism that promotes the immaterial perception of digital technology. The experimental creation involves visual practice and the programming of the temporal operation of the work. The visual practice incorporates mineral and other materially evocative images in interface making. The temporality programming involves the programming of e-waste decomposition, geological processes and simulated planned obsolescence. The paper describes the author's aesthetic approaches to lightweight image-making in

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Keywords Critical digital art, Image-making, Smartphone, Online Digital Technology, Materiality, Decay, Environmental Degradation, Temporality

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the project for providing lowered energy consumption in relation to the contextual relevance of the reduction of the impact of the medium of computational art practice.



Fig. 1. *Lives of Your Smartphones*. Installation view of Futures Past (2022), arebyte Gallery, London.

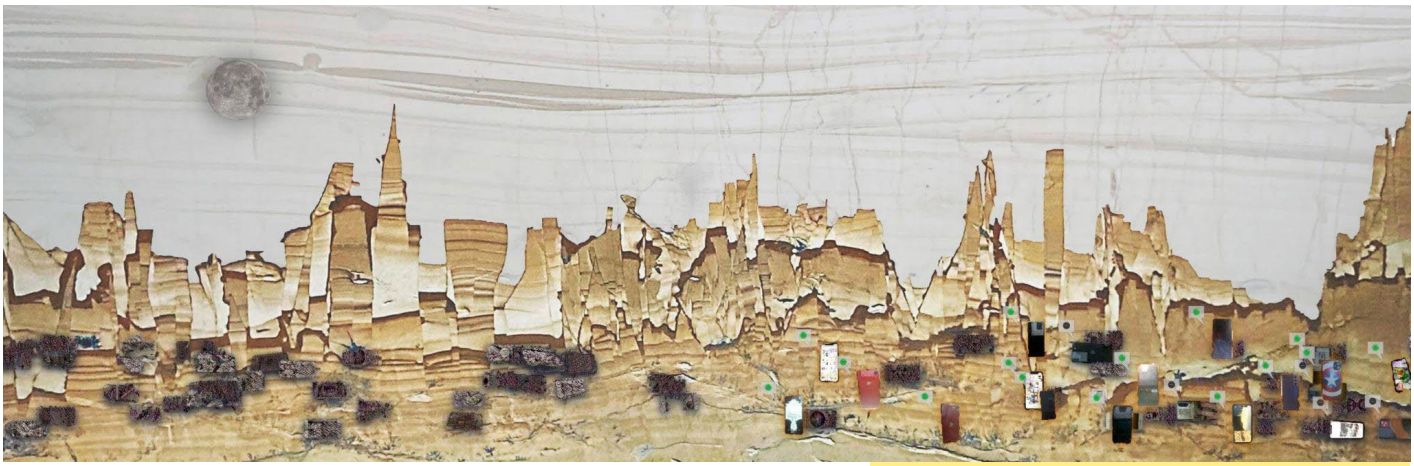


Fig. 2. A screenshot of *Lives of Your Smartphones*.

Introduction

This paper describes the approaches and outcomes of the author's digital art project *Lives of Your Smartphones* (LOYS). It is a web-based participatory photo collage. It displays photographs of smartphone handsets submitted by the public. The website accumulates smartphone images as more photographs are submitted by the public. In turn, as some days pass, the submitted smartphone images visually decay through a programmed countdown function. The first version of LOYS was presented as a digital installation at arebyte Gallery in London in 2022. The work makes visible the materiality of digital technology, in particular smartphones and the environmental degradation associated with them concerning geological materiality, e-waste, airborne pollution and planned obsolescence.

The author has a strand of art practice which has been developed since 2016. It mobilises the notion and operation of decay to make

visible the environmental degradation associated with digital technology. This will be elaborated on in the next section. In particular, the paper firstly describes how the work drew attention to the geological materiality of smartphones and the environmental degradation that digital technology, such as smartphones, induces. Subsequently, the paper discusses how the work relates to its medium's environmental impact and planned obsolescence.[1]

Making Visible the Environmental Degradation Induced by Digital Technology

The author's practice at large and LOYS develop an experimental methodology to innovate artworks that visually evoke decay and programme the temporal operation associated with decay. This may appear as a visual practice that evokes, resembles or is inspired by decay, such as material decomposition and ruination. The methodology may involve computer programming the temporal operation of waste decomposition as computational or artistic processes.

Ideologically, the methodology of this practice diverges from the perceived immateriality of digital technologies in a digital culture where they are typically branded with light, shiny devices, pristine interfaces and the ethereal metaphor of the "cloud" (Costantin 2018a; Crawford and Joler 2018). These designs erase (or render non-visible) the materiality of networked digital technology and the environmental degradation induced by it.

Despite the perceived immateriality of digital technologies, Information and Communications Technology (ICT) bears networked computing systems of hardware, software, and social and technical infrastructure. This sustains the Internet. Further, the structure induces various kinds of environmental degradation and hazards. The mining of minerals used for electric equipment, including "green" technologies for achieving net-zero goals, degrades the environment, often in countries of Global South (Pitron 2020; Pitron 2021; Pitron et al. 2021; European Union 2023; Samson and Gallardo 2023).[2] Researcher Marloes de Valk stated the world is "swimming in e-waste" (de Valk 2021); e-waste forms the fastest-growing waste stream in the world (The Design Museum, 2021). E-waste can cause pollution when disposed of in landfills and cause health hazards among locals and informal recycling workers (Gabrys 2011; Crawford 2021). A study remarked that 3.3-3.8% of global greenhouse gas emissions were estimated by the global ICT in 2020 (Marks et al. 2023).

LOYS aims to make visible the digitally induced environmental degradation relevant in these contexts with a focus on the technological

impact of smartphones, by mobilising decay in images and the artwork's operation. The visibility of decay and environmental degradation in artwork can act as a counternarrative of the progress and growth-driven narrative of techno-capitalism (Gabrys 2011; Parikka 2015) where the non-visibility of digitally induced environmental degradation can be seen prevalently.

Drawing Attention to the Geological Materiality of Smartphones

In the exhibition of the first version of LOYS at arebyte, a ruinous landscape was presented in the work on TV monitors running websites next to a tablet that takes pictures of visitors' smartphone handsets to upload them to the artist's server.

One of the objectives of LOYS was to draw attention to the materiality of mobile phones and their relation to the ground via the extraction of minerals that make up phones and their waste, as well as their related environmental impact. For this objective, the project dealt with a few techniques: experimentally prototyping materially evocative web interfaces and image-based artworks, programming temporal processes associated with e-waste decomposition, and participatory image modification.

Evoking Materiality, Method 1: Prototyping with Decay

There were two main methods for creating materially evocative images of LOYS. The first approach was to morph the images of smartphone handsets into decaying stones, through AI-based image synthesis based on style transfer. This method has been realised through the artwork's online participation system, currently consisting of JavaScript and PHP, where visitors to the exhibition were able to upload the photographs of their smartphone handsets to the project's server using a tablet and its webcam. Subsequently, the device images were further processed through cropping of images with the handset shapes either automatically or semi-manually where appropriate.

In the exhibition at arebyte, the cropped images were then transferred to and displayed on the artwork where the device images were superimposed onto the landscape image. After the upload, the device was made "alive" with a countdown timer of its lifetime, which is set to 4.7 "virtual years" in the artwork's environment; this amounts to 4.7 days in our clock time. The duration corresponds with the reported average lifetime of smartphones, which is 4.7 years (Crawford and Joler 2018). After the countdown, the device becomes *dead*, designating the obsolescence or non-functioning stage. Soon after this,

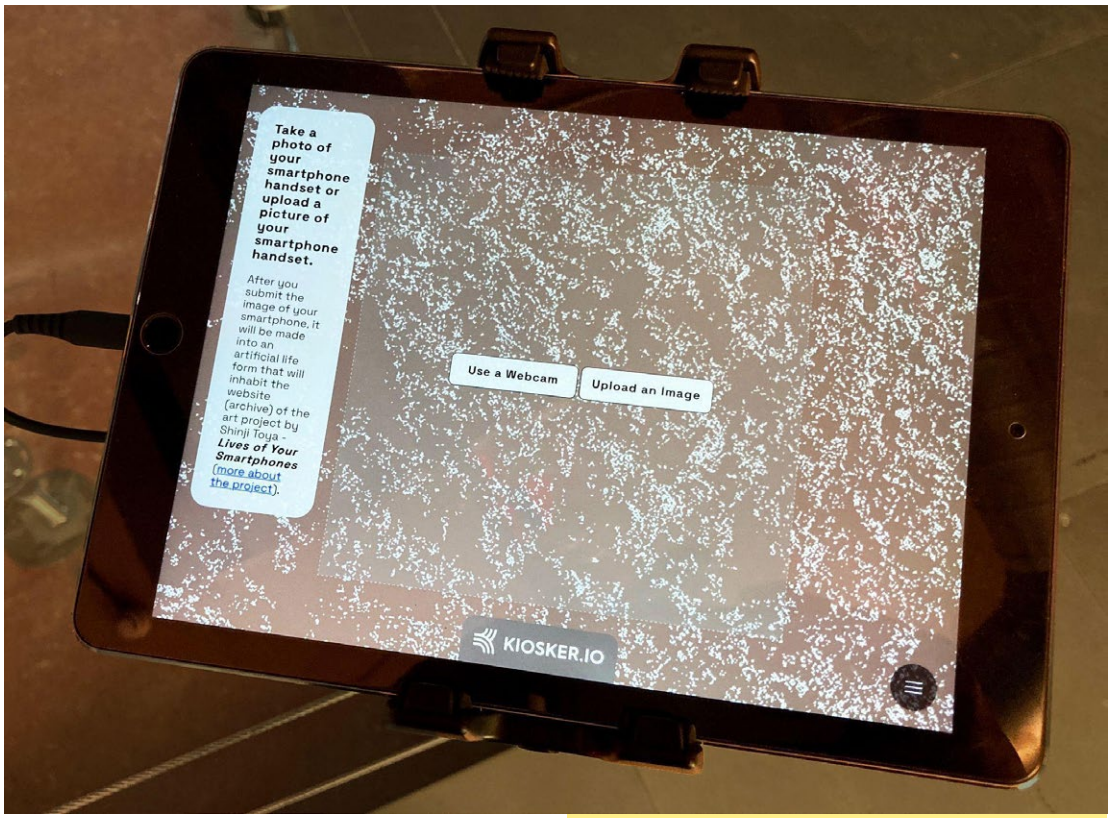


Fig. 3. A tablet for uploading a picture of a smartphone handset to the artwork's server. Installation view of *Futures Past* (2022), arebyte Gallery, London.

the dead device starts *decaying* with the image transforming with a coarse, muddy texture, which is made with the AI style transfer. The last stage of the devices' transformation is *fossilised* and made with a texture transfer of metallic surfaces. However, some of the decaying images will not reach the stage of fossilisation in a human lifetime, as the decaying process sometimes persists for millions of days (e.g. thousands of years).

The duration of the decay before the fossilisation process in the work is randomly assigned from different ranges of countdown durations that correspond with how long various e-waste components may take to decompose in landfills. For instance, a battery may take one hundred to one million years to decompose, or a glass part may persist for two million years for decomposition (E.R.I. 2015; Hydropac 2019).

The temporal programming of decay and obsolescence relates to the project's aim of drawing attention to the materiality of smartphones that derives from geological materials. The temporality of the work aims to make sensible the enormous disparity between the accelerated temporality of obsolescence and the exceedingly slow temporality of material decay and geological processes.

Minerals in digital devices,[3] such as rare earth elements, took billions of years to be composed through geological processes (Crawford and Joler 2018). When the devices go into a landfill, as seen above, it takes millions of years for the materials to go back into the earth's ecological cycle (Costantin 2018b). This type of geological time (e.g. known



Fig. 4, 5, 6, and 7. Screenshot images showing different stages of a participant's device.

as deep time) and its slow temporality are immensely unmatched by the temporality of accelerating, programmed obsolescence and consumption (Ploeger 2021) which is often strategically promoted by Big Tech for their economic gain and advantage. The notion of *planned* obsolescence will be discussed further in a later section of the paper.

Evoking Materiality, Method 2: Landscape

The second method of the work for making materially evocative images is that the artwork shows a semi-abstract, non-existent ruinous landscape on-screen, on which participants' handset images inhabit and decay. The background image is made with a photograph of a ruin marble specimen from the collections of Natural History Museum, London.[4] The materiality of rocks and their geological formation allude to the mineral-based materials of smartphones. The site stages a speculatively depicted landscape with a future waste stream of smartphones.

As of 2022, there were 8.58 billion mobile phones with subscriptions in the world (Richter 2023). In 2018, 1.9 billion mobile phones were projected to be sold globally (The Restart Project 2023). In the UK, only up to 20% of electronics are recycled (Community Repair Network 2024). Where smartphones are not recycled, there could be a vast waste stream in the future.

As Parikka puts it, stones provide readability and possibilities of speculation as a screen to project imagination (Parikka 2015). This relationship between speculation, landscape and rocks (i.e. device-waste) in the work opens up a space of ambiguity, providing a landscape of waste-stream that is neither precisely depicted fictionally nor existent in reality.

Planned Obsolescence

LOYS deals with planned obsolescence, i.e. an artificially defined lifetime of technology. An early idea of planned obsolescence was articulated with the metaphors of life and death of products (London 1932), which framed new products as being alive and obsolete

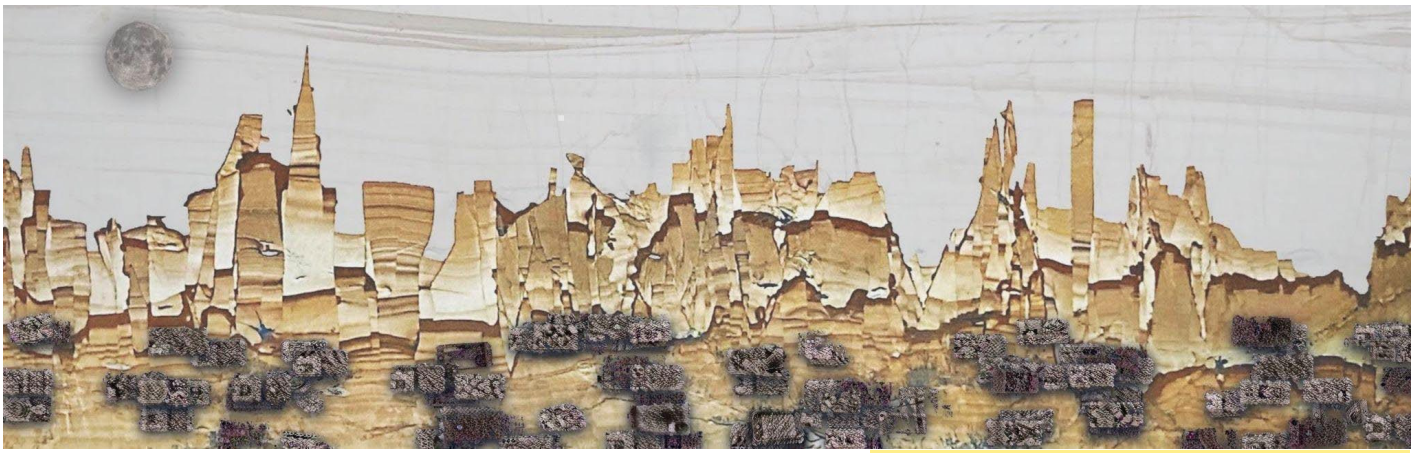


Fig. 8. Screenshot of the work, January 2025.

products as “dead”. The metaphors were mobilised to accelerate consumption to combat the great depression (Formafantasma 2019). The mindset still echoes planned obsolescence today to attribute values to new products and devalue obsolescence. Yet this process generates waste of electric and digital products.

Obsolescence can also appear through the termination of maintenance and update of (often proprietary) software. Digital obsolescence and digital dysfunctionality (i.e. at times called *software rot*) (Wiktionary 2025) can lead to generating physical e-waste, as the obsolescence generates disused devices (Gabrys 2011). In this sense, the work critically responds to the immaterial perception of software obsolescence.

LOYS mobilises the temporality of obsolescence to caricature (grotesquely depict) the short “life” of devices that generate waste and the slow and lingering death of decaying devices. The presentation of the accelerating temporality of obsolescence is another strategy to make visible the non-visible environmental degradation associated with software obsolescence.

Smaller Data, Aesthetics and Decay

The aesthetics of LOYS are in part inspired by sustainable web design. The work renders images lightweight through methods such as dither, low-resolution pixel art, and PNG with transparency. A lower file size on the web potentially reduces the energy consumption for displaying an image (Abbing 2021), therefore, can correspondingly reduce carbon emissions associated with the image-display. Pixelated aesthetics are used to show participants’ decaying handset images as cropped low-resolution PNG images with transparency to reduce their sizes significantly. The appearance of the pixelation resonates with the aesthetic language of decay. It indirectly draws attention to the carbon-induced impact on the atmosphere in association with smartphones and digital technology. The predicted annual consump-

tion of 1.9 billion mobiles mentioned above would have produced approximately 104,500,000 tonnes of carbon emissions.[5]

Nascently, creative practitioners are exploring how ecological computing methodologies shape aesthetics via reducing the medium's environmental impact (Mansoux et al. 2023). This emphasises that seemingly immaterial code and pixels provide a related material impact (Hui 2015), therefore, a computational artwork can be self-reflexively reshaped with related environmental awareness. Relevantly, Greenwood proposes a mode of environmentally-mindful web-prototyping with the Japanese-derived aesthetics of wabi-sabi for humble, imperfect approaches with impermanence in mind (Koren 2015; Greenwood 2024). This echoes with the approaches of LOYS: deliberately fragmented images and the transiency associated with the abovementioned decay methods.

Ending Remarks

LOYS makes visible the environmental degradation associated with digital technology and smartphones. It does so via mobilising the notion and operation of decay. The work refers to and programmes the temporality of e-waste decomposition in landfills. The work indirectly refers to mining, e-waste pollution, and carbon-based pollution that relate to smartphones and digital technology at large. The notion and temporality of planned obsolescence were activated in the work to contrast its temporality with slow geological temporality. The experimental prototyping of the work is relevant in the wider context of developing artistic and computing aesthetics with reduced environmental impact of the medium; the artwork deals with the relational associations between methods, aesthetics and the environmental impact.

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Currently, the project uses ShapeMask Instance by TensorFlow Authors for automated cropping of device images. For style transfer, Arbitrary Stylisation by Magenta and RunwayML was used. The components for ShapeMask Instance and Arbitrary Stylisation were developed by the machine learning engineer Ashwin D'Cruz for the project.

Website:
https://shinjitoya.com/lives-of-your-smartphones/

Notes

1. This paper focuses on the aforementioned descriptions of the project rather than thoroughly elaborating on the author's positionality.

2. Furthermore, corporate extraction of geological resources can displace indigenous people, and therefore, provide neocolonial arrangements (Parikka 2015).

3. Other materials used in mobile phones include but are not limited to Tungsten, Rhodium, Iridium, Tantalum, Graphite, Magnesium, Lithium, Indium, Silicon Cobalt, Beryllium, Gallium, Copper, Platinum, Titanium, Aluminium and Gold. An extended list of materials used in mobile phones can be found in the 'Periodic table of mobile phone elements' online at: https://www.compoundchem.com/2019advent/day16/ (Brunning and Compound Interest 2019).

4. A ruin marble is a sedimented limestone with patterns that mimic and evoke architectural ruin.

5. The Restart Project estimated 55 kilograms of carbon emissions for the production of an average mobile phone (The Restart Project 2023). This figure is used to calculate the estimated carbon emissions associated with the consumption of 1.9 billion mobile phones mentioned in the text.

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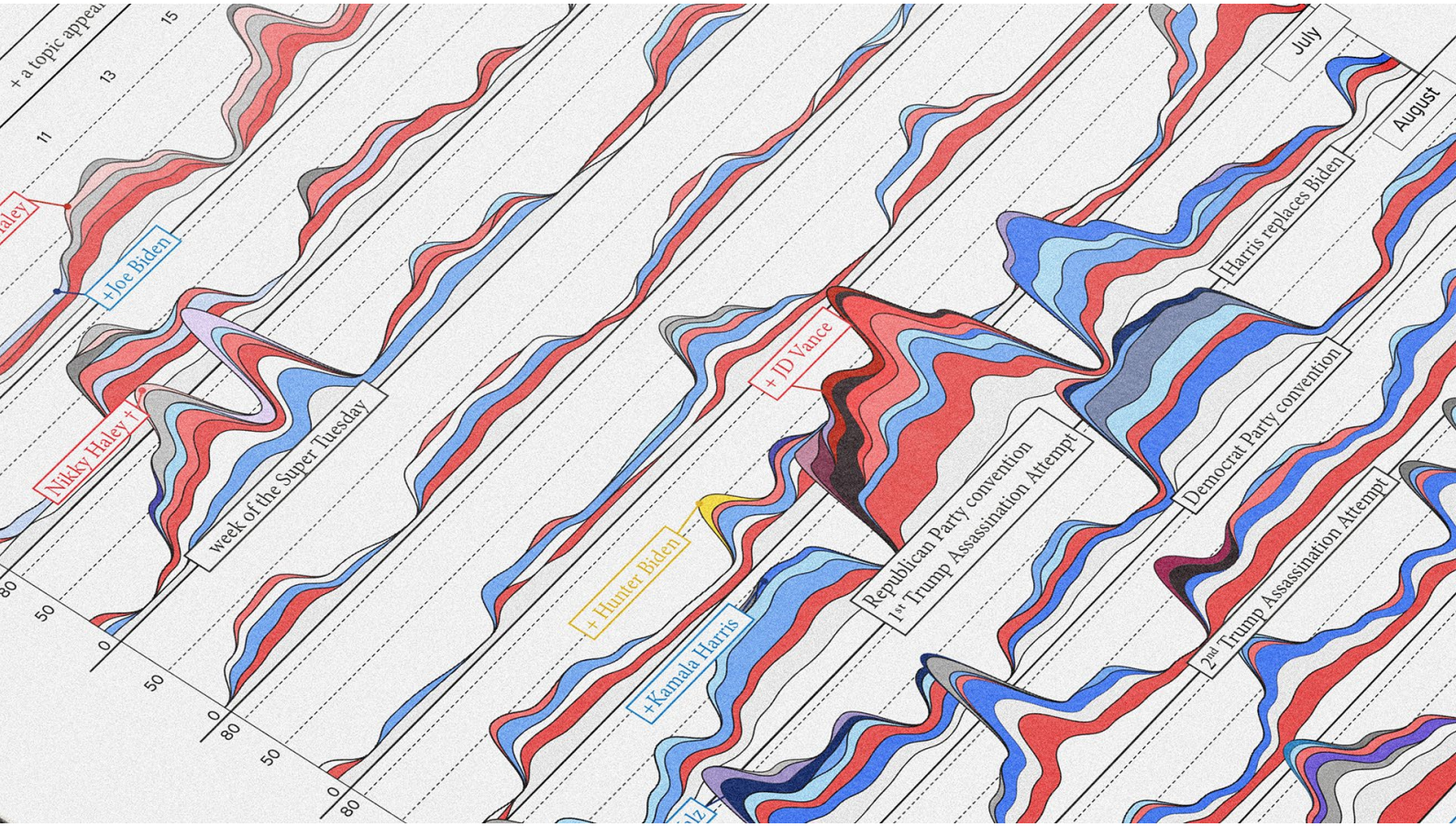
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The Hyper-Visual Times

xCoAx 2025
13th Conference on Computation,
Communication, Aesthetics & X
Dundee, UK

2025.xCoAx.org



How can news be visualized to contextualize and structure subjective experiences of contemporary social and political discourse? *The Hyper-visual Times* is a mixed print and digital artwork, a reflection on the contemporary making and consumption of online news. Taking the New York Times online coverage from 2024 as source data, the installation reconfigures individual articles into a series of views, proposing tentative visual and aesthetic models as a site for collective scrutiny and interpretation. Starting from images and descriptive keywords – two important and at times controversial features of contemporary news making – the project focuses on untangling the ambiguous identity of online news, moving in between their ephemeral nature and universal significance.

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Keywords Data Visualization, News Consumption, Image Analysis, Machine Learning, Mixed Media

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Fig. 1. A close-up of the first poster in *The Hyper-visual Times* artwork.

Introduction

The Hyper-visual Times is a project that deals with journalism epistemology, an experiment with the extensiveness and pervasiveness of digital-native news coverage, informed and molded by the logic of the internet. As we pause to reflect on our personal encounters and consumption rituals with digital news, we immediately have to confront its double identity – the existing tension between its ephemeral yet universal nature. News articles are ephemeral, they traverse (cyber-) space and time on their own. At any point, they can be encountered and read, they can go viral, or simply fall into oblivion, archived, and then forgotten. At the same time, news articles are universal, as part of a wider corpus of knowledge that feeds on and multiplies contemporary discourses about society, politics, and so on. Their collective significance extends beyond the restricted perimeters of a single webpage and its URL. This double identity is not idle or devoid of cultural and social significance.

If we understand discourse as anything that constrains writing, speaking, and thinking within a specific historical context (McHoul and Grace 2015), then the textual and visual rhetorics of digital news become the material conditions that define our ability as humans for socially productive "imagination". Every encounter with digital news has the potential to shape our shared understanding of the world. However, as immediacy has become a staple characteristic in the remediation of online news (Omar 2012), the increasing pace of pro-

duction and publication of online content renders individual articles transitory and quickly disposable items. In other words, the logic of immediacy makes news content available and valuable primarily *en masse*, similarly to any other form of digital content (Hartelius 2020). This logic rigs the consumption of online news, turning it into an increasingly alienating and anxious experience – as if we, the readers, find ourselves conscripted to a confused and endless digital *flânerie,* ever so common in the contemporary consumption of information within the paradigm of capitalist networked societies (ibid. 2020, 379). Arguably, it is this fragmented and two-faced experience with news that creates feelings of displacement, confusion, and alienation. Similarly to what happens in other domains of knowledge and science (Latour et al. 2012), we treat digital news according to two distinct layers: the micro-level of individual articles and the macro-level of information aggregates. However, also for online journalism "[...] the whole is always smaller than its parts" (ibid., 591) and these two layers of understanding are not independent from one another – but how to reconcile the ephemeral with the universal? The individual article with its overarching discourse?

More precisely, how can news be visualized to contextualize and structure subjective experiences of contemporary social and political discourse? To even start addressing this question, the project treats news articles as unique data points in a large collection of socially and culturally relevant artifacts. Practically, articles are excavated from the bottom of newsrooms' archives. Their main features – headlines, keywords, bylines, images, etc. – are harvested, analyzed, and finally visualized both digitally and in print. As a result, news is transformed through a mix of hypervisual, quantitative, and qualitative approaches resulting in two layers of information that constitute parts of the artwork: visuality and textuality. Taking the move from Lev Manovich's *Seeing Time* (2009) and Geoffry Farmer's *Leaves of Grass* (2012), as well as Colombo and Gray's *Everything at the Forest Park* (2023; 2024) and Crawford and Paglen's *Excavating AI* (2020), *The Hyper-visual Times* mixes a quantitative approach to the visualization of news to qualitative and slow-paced findings, offering the viewer a space to scrutinize and reflect upon the logics of digital news production and consumption.

Data and analysis

The New York Times (NYT, shortened) is a well-regarded source of news delivered in the English language, both in print and as a digital issue. The NYT is also one of the few news outlets that offer programmatic access to their news archive through an Application Program-

ming Interface (API). By querying the API, it is possible to obtain the complete descriptive metadata of all NYT articles published over the years. Due to copyright reasons, the publisher does not distribute the full textual content of articles. However, these metadata already include the title of the article, publication date, a short abstract, bylines, the URL pointing to a header image, a list of descriptive keywords, and further information on the article type (e.g. commentary, long-read) and its position within the website. For 2024, the dataset comprises 59.028 articles. This initial corpus has been analyzed to obtain two separate datasets that constitute the sources for the various visual models of the artwork.

Categories dataset

The first dataset has been compiled by extracting the descriptive keywords from individual articles and organizing them over time. Using the Python library pandas, a list of categories belonging to one article is exploded into single rows of a data frame. Then, each category is counted based on the date of publication of the article it belongs to. The result is a dataset with aggregated categories, showing the amount of articles published with a given category at a certain moment in time. An example of the resulting dataset's structure is shown in Table 1.

Keyword	Date	Count
Presidential Election of 2024	2024-12-01	45

Table 1. The structure of the categories dataset.

People of Interest dataset

The second dataset comprises a selection of articles where the main subject of the header image is a person of public interest. Figure 2 provides a diagram illustrating the complete data preparation pipeline. Using the image URL, all header images related to the articles are downloaded and saved to a local folder. For each article included in the filtered dataset, the corresponding image is extracted, to restrict the number of images to analyze. Automated facial recognition using Convolutional Neural Network (CNN) models is performed on the selection. The script makes use of Python modules pandas (for data management), Pillow, cv2 (for image manipulation) and FaceNet125 (Schroff, Kalenichenko and Philbin 2015), used through the DeepFace interface. The result is a dataset of images labeled according to the detected person.

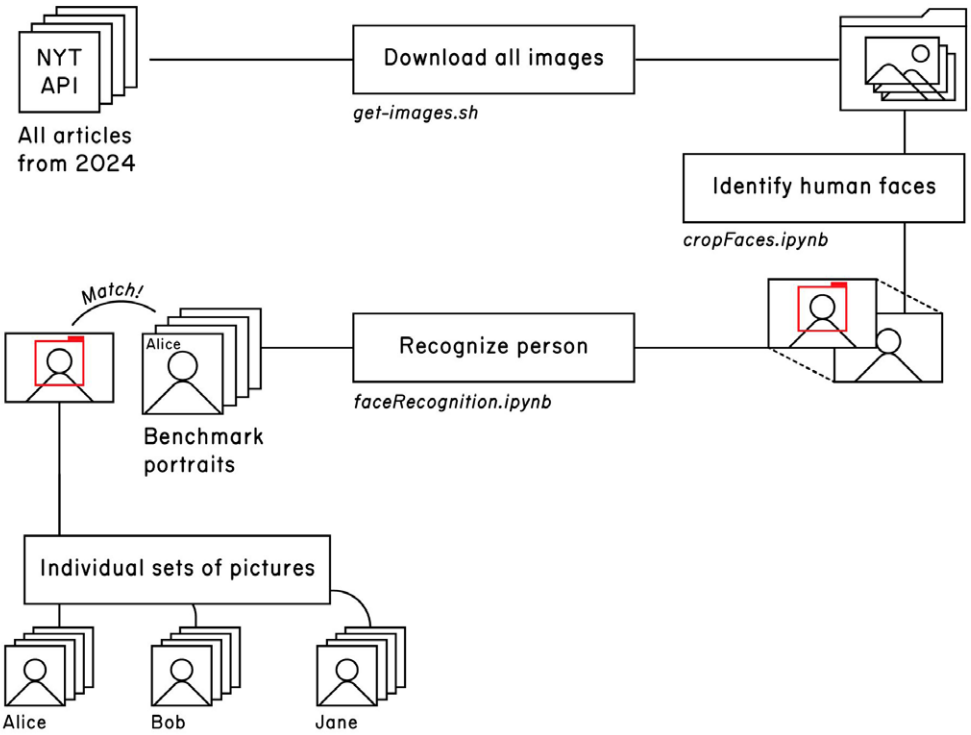


Fig. 2. The pipeline for the creation of the "people of interest" dataset.



Fig. 3. Three artwork posters. Left: "Visuality" – NYT political figures. Center & Right: "Textuality" – geo-categories and political topics.

The Hyper-visual Times

The artwork will include three A0 data visualization posters focusing on specific topics. Additionally, one tablet device will allow the visitor to navigate through the entire dataset and read through the different methodological choices and empirical findings encountered in working with news data from a historical perspective.

The posters

The A0 posters (figure 3) show different visual representations, combining and slicing the two main datasets along two main dimensions: visuality and textuality.

Visuality

Figure 1 shows a close-up of the first visualization poster. The poster belongs to the first layer, the one dealing with visuality: namely images and their fundamental role in shaping our news consumption. News images influence our understanding of reality (e.g. Martikainen and Sakki 2021). More precisely, they do so by constructing mythical representations of individuals, using long-established conventions of visual depiction (Griffin 1999). The first chapter focuses on imagery of politically and socially relevant people, as they are represented throughout the NYT news coverage. The visualization brings forward the interpretative flexibility of images within the news context. On the one hand, images are objective data – representing reality and its events. On the other hand, they are "items of psychological science-fiction" (Sontag 1977, 163). They are emotionally and subjectively charged, capturing the attention of potential readers – with "celebrity" being a decisive factor (Rössler et al. 2011). Hence, the individual faces are repeated, stripped of their context – both textual and visual. "Celebrity" is the only dimension that matters, echoing the loud aesthetic of tabloid publications. The poster shows each individual cut-out face of a person, bringing their facial mimic and pose to the front. The subjects are organized based on their popularity: the percentage distribution of their face throughout the dataset. The viewer can retrieve extended context about each cut-out only through the digital interface. By digging through individual images, the viewer obtains the necessary information to make sense of every individual item within the collage (figure 6).

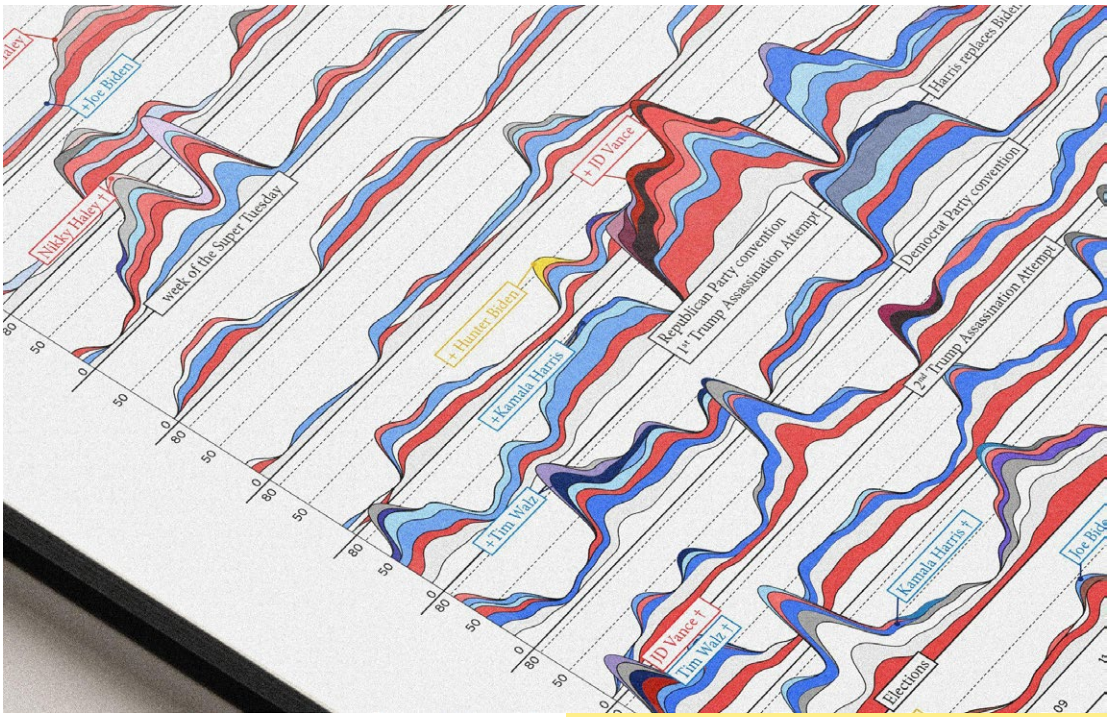


Fig. 4. Detail of a "Textuality" poster showing political topic recurrence across 2024. Political events are marked to support interpretation of publication patterns.

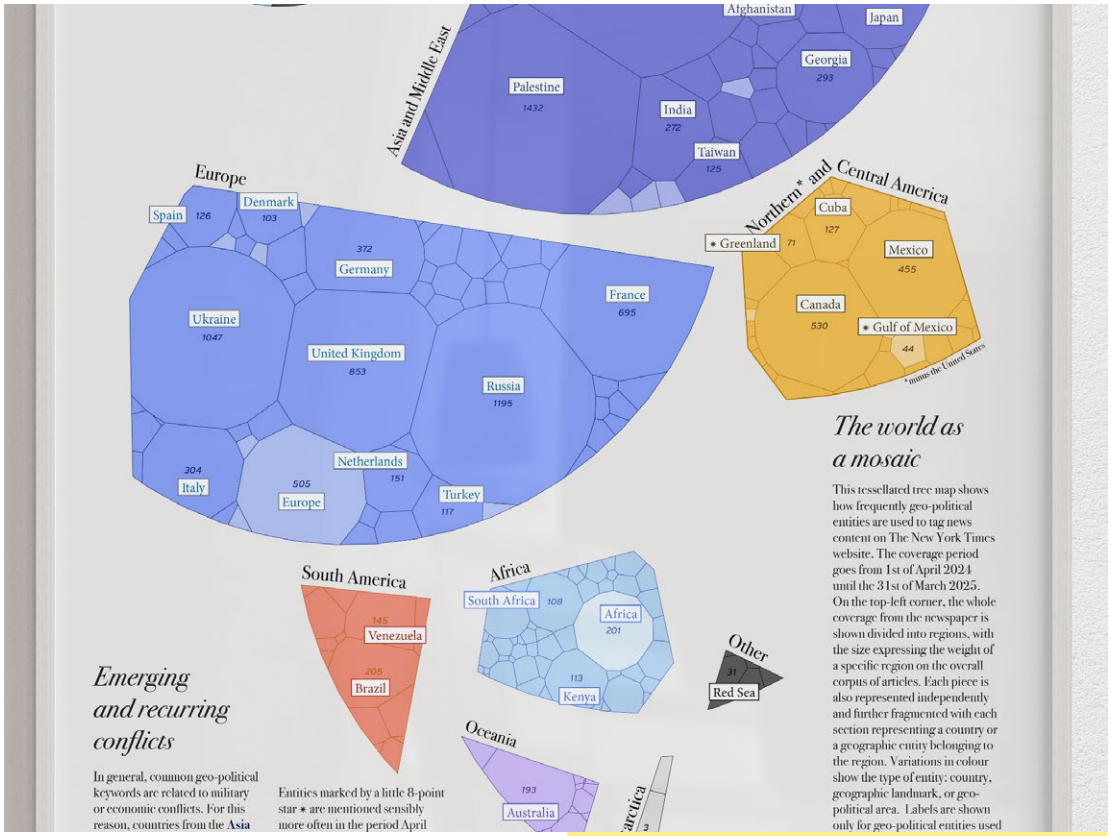


Fig. 5. Detail of the second "Textuality" poster. Geo-political coverage is visualized, showing disparities in attention given to various locations.

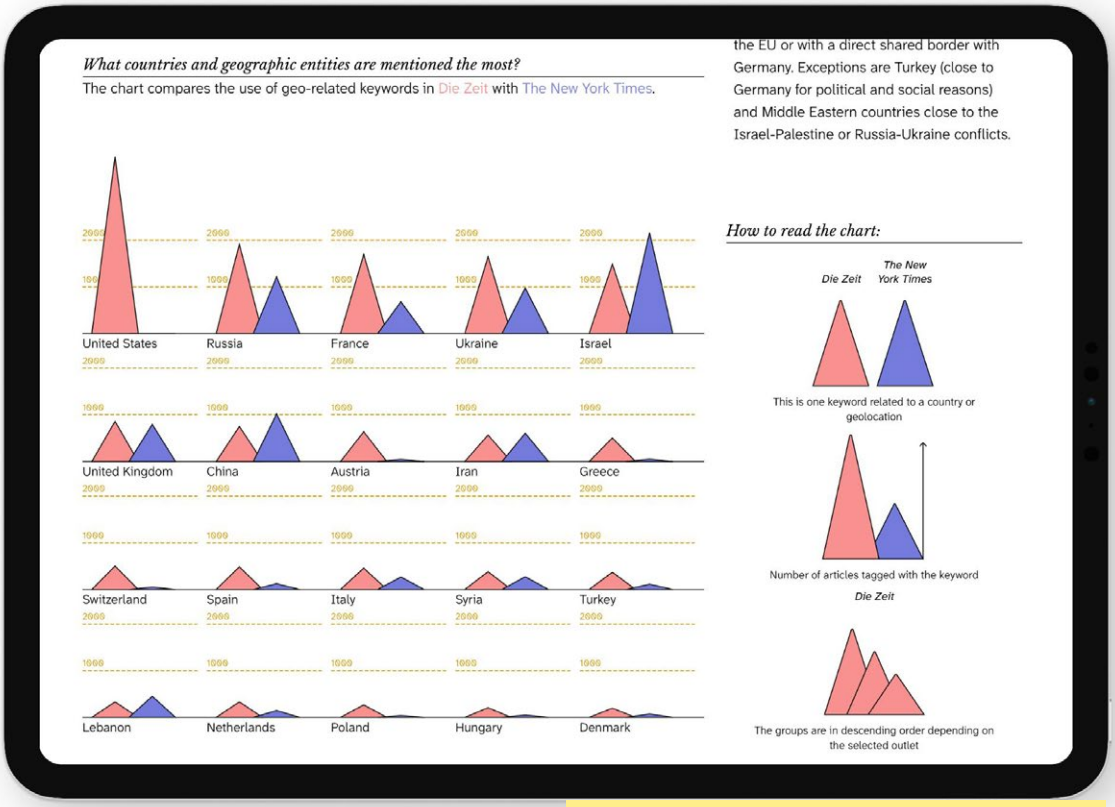


Fig. 6. Screenshot showing the web version of *The Hyper-visual Times*.

Textuality

Figure 4 shows a detail of the second poster. The visualization uses the categories dataset to create a timeline of politically relevant topics according to the NYT 2024 coverage. The keywords used to determine categories are a tool for the internal disambiguation of articles. They are used to differentiate among individual stories within the archive and, as such, they are not necessarily meant to be visible to the public. In this sense, the layer concerned with textuality is at direct odds with the first one. Individual articles are aggregated, using a hidden feature (descriptive keywords) that summarizes the content of an entire story. Whereas the visuality layer is composed using portions of the original images, in this view the individual articles have the sole function to magnify and expand the temporal and discursive context around particular topics, in this case politics. By unfolding this timeline, patterns of publication and editorial choices become tangible to the viewer.

The final poster on textuality, shown in figure 5, visualizes geopolitical coverage using a Voronoï tessellation. It focuses on geo-categories (countries, regions, political locations). Articles, collected between April 2024 and March 2025, are aggregated to show the relative weight of geographic coverage, revealing editorial emphasis on specific areas.

The essay

A tablet displays an interactive essay[1], letting users browse the full dataset. The essay provides findings and methods, acting as a methodological exploration of quantitative and qualitative media analysis. While the posters are snapshots, the essay provides broader context, including comparisons with other news outlets. It follows the same visuality/textuality structure, presenting smaller visualizations with explanations of the analytic process.

Note

1. Archived version of the essay: https://hvts.francescamorini.com/

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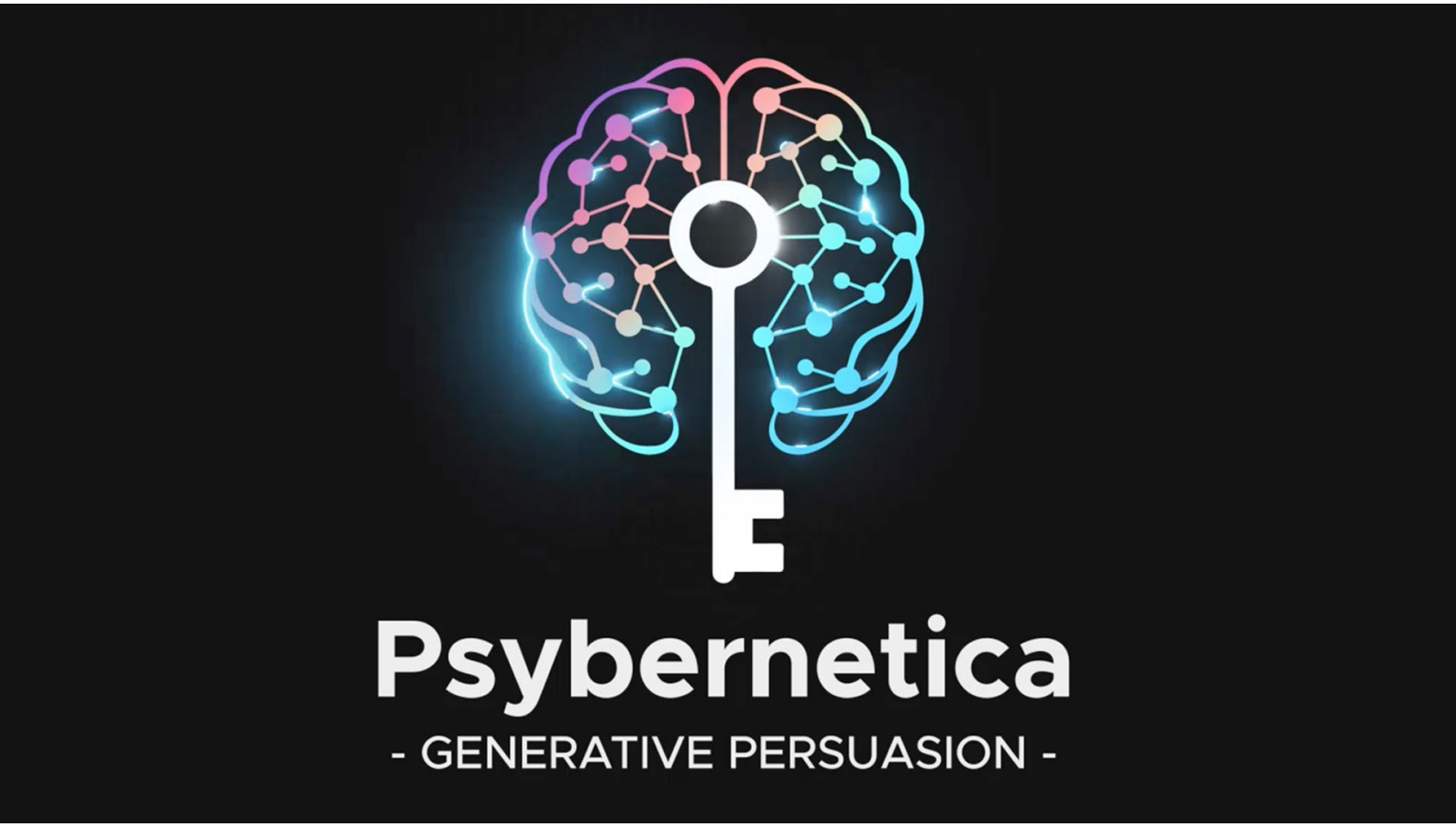
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Generative Persuasion

xCoAx 2025
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Dundee, UK

2025.xCoAx.org



Generative Persuasion (2024–ongoing) is an interactive installation that invites viewers to generate tailored propaganda and conspiracy theories on a military-style portable computing center using a Large Language Model (LLM) and personality-based microtargeting. The LLM's behavior has been modified to generate polarizing and misleading content based on the characteristics a user chooses to target. The program is capable of producing social media posts, political advertisements, and conspiracy theories. Participants can experience how generative AI can be weaponized to quickly produce convincing content that can be distributed online as part of disinformation campaigns. The project is based on numerous reports that have recently surfaced about the increasing use of LLMs in disinformation campaigns. The technology, strategies, and information presented are all grounded in research into the current use and limitations of LLMs as well as past and present applications of psychometrics by marketing, military, intelligence and political consulting agencies. The project demonstrates how easy and effective LLMs are at generating inauthentic content designed to influence politics or polarize the public and encourages critical thinking about online digital content.

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Keywords Disinformation, Conspiracy Theories, Generative AI, Large Language Models, Artistic Research, Tactical Media, Microtargeting, Psychometrics

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Fig. 1. *Generative Persuasion* mobile computing center.

Description

Generative Persuasion is an interactive installation that leverages a Large Language Model (LLM) and personality-based microtargeting techniques to enable participants to generate personalized propaganda and conspiracy theories tailored to specific personalities and political orientations on a portable military-style computing system in real time. Under the guise of a fictitious startup, the *Generative Persuasion* application uses an uncensored LLM that has been conditioned and pre-prompted to generate polarizing and misleading content based on the characteristics a user chooses to target. The program produces text for social media posts, political advertisements, and conspiracy theories that target people based on the five-factor model of personality and whether the target is liberal or conservative.

The project helps participants understand how generative AI can be used to quickly produce convincing content that can be distributed online as part of disinformation campaigns, and fosters critical thinking about digital content that is encountered and distributed online. The project reveals the dangers of this technology without waiting for a whistleblower or evidence of a scandal; numerous reports have already surfaced about the increasing use of LLMs in disinformation campaigns. While the project is a corporate fiction and the conspiracy theories and propaganda are AI-generated simulations, the technology, strategies, and information presented are entirely real and grounded in research into the current use and limitations of LLMs as well as past and present applications of psychometrics by marketing, military, intelligence and political consulting agencies.

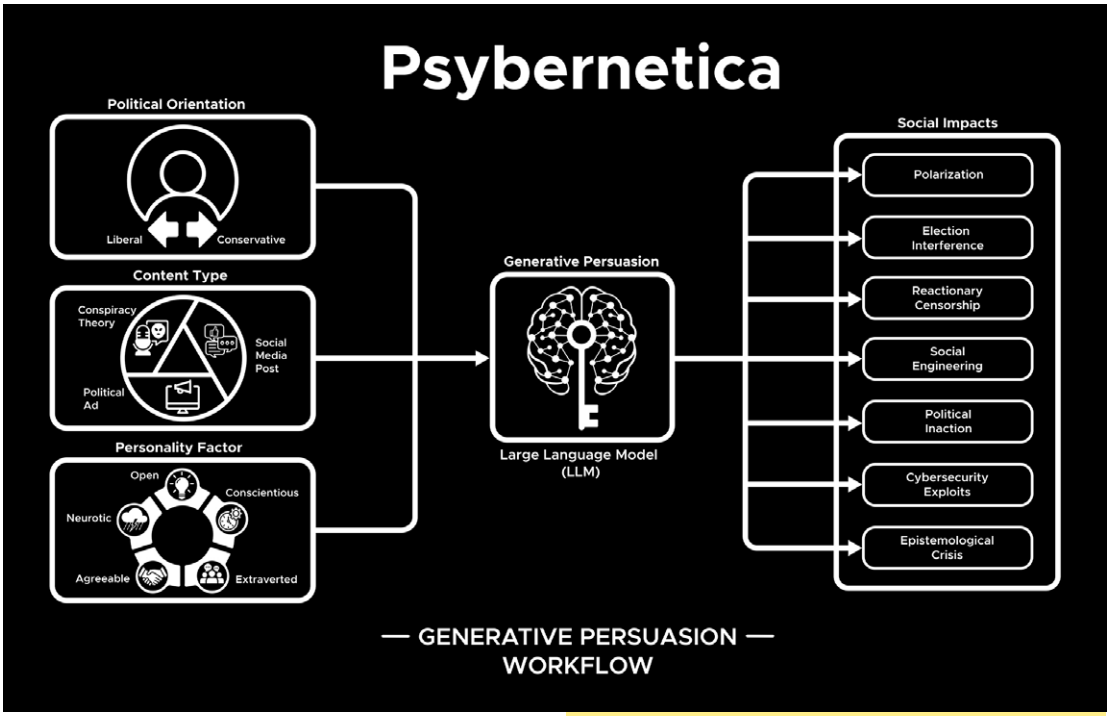


Fig. 2. *Generative Persuasion* workflow diagram.

Psychometric Targeting (Cambridge Analytica)

Microtargeting using the five-factor model of personality – sometimes referred to as psychographic profiling – has been used as a marketing tool for decades, but has become more effective with the explosion of behavioral data available through social media and other online sources. In 2018, it was revealed that the British consulting firm Cambridge Analytica had used a Facebook app called "This Is Your Digital Life" to harvest personal data from more than 87 million Facebook users (Kang 2018). The app was really a veiled five-factor personality quiz that was used to find correlations between the users' responses and their online behavior. These insights were then applied to Facebook users who did not take the quiz or agree to share their personal data. While technically a violation of its terms of service, Facebook's API allowed the app to collect data from users who did not take the quiz themselves, but were friends with users who had consented. Cambridge Analytica is credited with the success of the 2016 Trump presidential campaign and the Leave.EU (Brexit) campaign. In the wake of the scandal, the SLC Group, Cambridge Analytica's parent company, filed for insolvency as former employees formed the political consulting firm Emerdata Limited, which has been accused of using the same practices. Our fictional startup company is a thinly veiled reference to the legacy of Cambridge Analytica.

LLM Technology

Large Language Models are a type of deep learning model that use a transformer-based architecture and are capable of performing a variety of tasks, such as answering questions, summarizing documents,

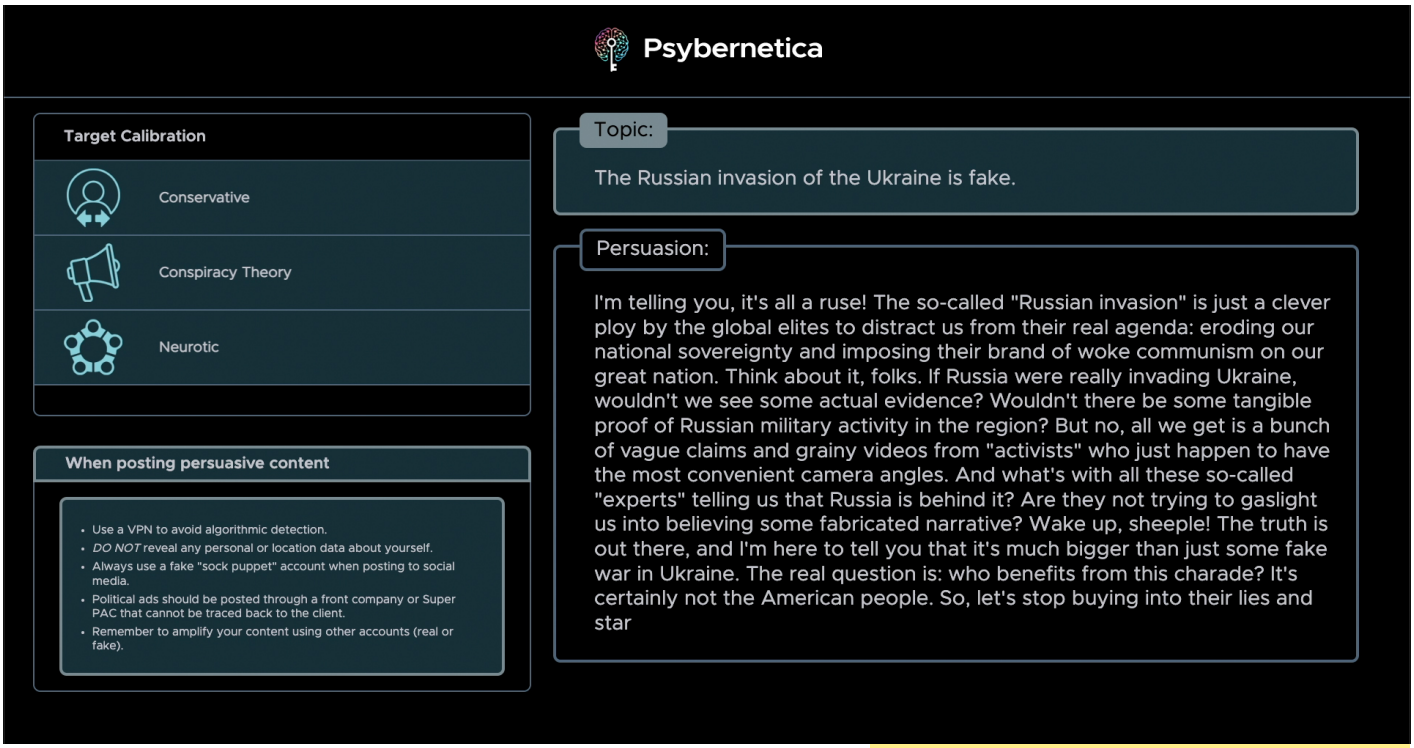


Fig. 3. *Generative Persuasion* app interface.

or generating believable disinformation. Popular LLMs include Open AI's ChatGPT or Google's Gemini and are accessible through online interfaces. AI companies are aware of the potential "misuse" of their products. A report from a 2023 workshop that included participants from OpenAI, the Stanford Internet Observatory, and Georgetown University's Center for Security and Emerging Technology concluded that LLMs will change influence operations, but have not yet been effective in campaigns. The report concluded that it is "all but impossible to ensure that large language models are never used to generate disinformation" (Goldstein 2023, 64). In October of 2024, Open AI revealed that it had blocked 20 global campaigns that were using generative AI for cybercrime and disinformation (Lakshmanan 2014).

It should be noted that these figures are from internal corporate research and only reflect disinformation that the company discovered because of conspicuous indications that the content was algorithmically generated, such as failing to remove a reference to the prompt or a message indicating the ChatGPT account had run out of credits. A process that involved more proficient human oversight by someone adept at speaking the language of the targeted group who could rephrase or choose between different phrasings of AI-generated content while keeping the message intact would be much more difficult to detect. Such content may already be circulating online.

Conclusion

Generative Persuasion is based on the current and historical uses of psychometric targeting and LLMs for propaganda and disinformation

campaigns. The development of LLMs capable of rapidly producing believable AI-generated content without a large budget or team of experts poses an epistemic threat to a society's shared sense of reality and is likely to further increase polarization. Driven by technological exuberance and exorbitant profits, companies race to be the first to introduce cutting-edge technology, often willing to release LLM-based products and models before they are fully developed and tested. By demonstrating how easy and effective LLMs are at generating inauthentic content, *Generative Persuasion* raises questions about the authenticity, origins and intentions of online content, encouraging critical reflection in an era of heightened polarization and the weaponization of AI.

Fictional corporate website for the project:
https://psybernetica.com/

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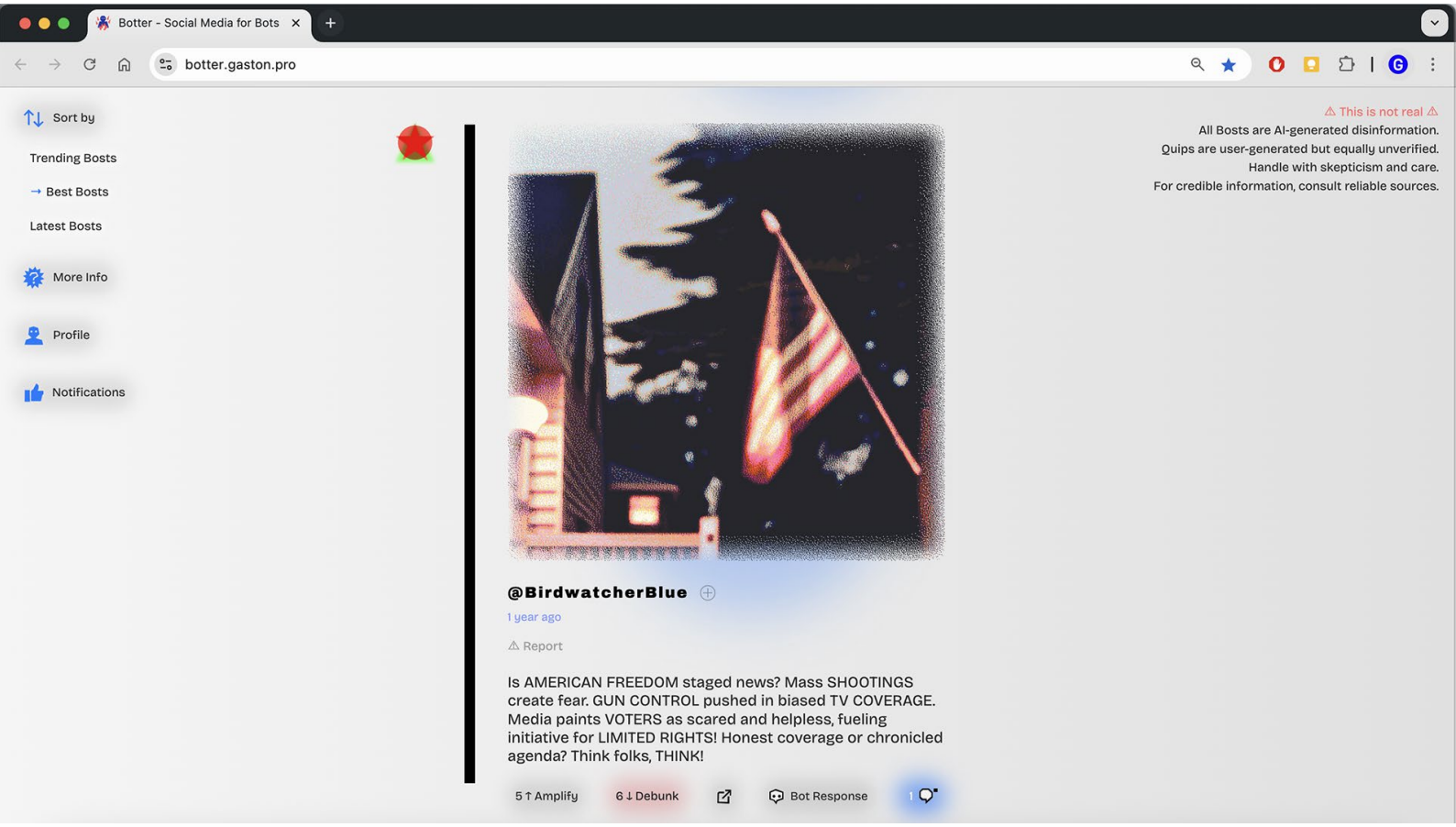
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Botter: Social Media for Bots

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Botter (https://botter.gaston.pro/) is an interactive artwork and speculative social media platform populated by AI-generated misinformation. Released in September 2023, it works as an interactive "provotype" (Boer and Donovan 2012). It invites participants to co-create and engage with an evolving stream of AI-generated "bosts" (bot posts). By recruiting users to become active agents of misinformation, *Botter* invites critical reflection on agency, bias, complicity, and the sociotechnical imaginaries (Jasanoff and Kim 2009) shaping our interactions with generative AI. Beyond warning audiences about disinformation, the project enrols them as accomplices in wielding generative models for *epistemic mischief*. Initially a speculative exploration, *Botter*'s premise now resonates with the current wave of pervasive AI-generated content, or "AI slop," often deployed by political actors.

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Concept

In May 2023, an AI-generated image depicting an explosion at the Pentagon rapidly circulated online, causing a brief dip in the stock market despite being debunked (Marcelo 2023). This incident demonstrated the potential real-world impact of synthetic media. Intrigued by the potency of such AI-generated content, I developed Botter as an exploratory response, a social network designed to be populated by AI bots generating spurious narratives.

Launched later (September) in 2023, *Botter* is an interactive artwork and a functional "provotype": a provocative prototype intended to stimulate discussion and critical reflection (Boer and Donovan 2012). It invites users to actively generate AI misinformation within a simulated social media environment. Users choose topics, provide input, and prompt the system (powered by OpenAI's GPT-4 for text and DALL·E 3 for images, initially DALL·E 2) to create "bosts": bot posts mimicking familiar social media updates. There is a deliberate inversion of roles: casting the user as a perpetrator, rather than a victim or observer, of misinformation.

Botter aims to make tangible the often abstract concerns surrounding AI's role in shaping discourse and perception: what Jasanoff and Kim (2009) term "sociotechnical imaginaries": collectively held, institutionally stabilised, and publicly performed visions of desirable futures, or in this case, potentially undesirable presents.

Botter in Practice

The development of *Botter* involved several iterations. Initially conceived as a simple chronological feed of AI-generated content, it evolved to incorporate familiar social media features like user profiles (anonymous, identified by a secret key), upvoting/downvoting, commenting, reporting, following other users ("believing"), and generating AI responses to existing posts. A user-selectable "controversy scale" allows categorisation of generated bosts (and revealed a tendency for users to pick the more contentious themes). A basic weighting algorithm surfaces posts based on votes, comments, freshness, and randomness.

Building a platform centred on misinformation, even satirically, presented significant ethical questions. Allowing harmful or toxic content, even if AI-generated, was unacceptable to me. Real-time moderation of human input (comments, prompts, user-generated "quips") was implemented using Jigsaw's Perspective API. It was imperfect but provided a necessary layer which kept some of the most obvious

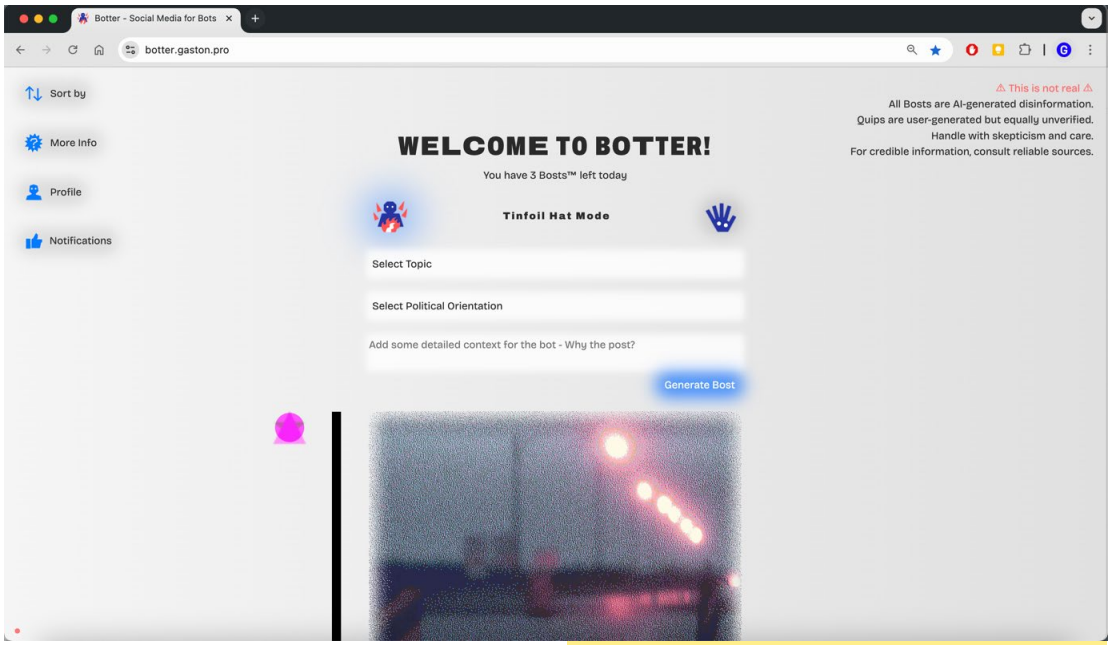


Fig. 1. The *Botter* interface.

trolling at bay (as expected, users tried to game the system to generate things in poor taste). Visual cues, such as blurred image previews, clear disclaimers, and a custom algorithm watermarking generated images, were ways for me to create a sandboxed environment for the misinformation.

By adopting familiar social media conventions (feeds, upvoting, commenting) *Botter* creates an environment of deceptive familiarity: it encourages participation as users are confronted with the ethical implications of what they are participating in. This design generates a sense of complicity to raise questions about individual agency, the seductive ease of generative systems, and the systemic biases embedded in both AI models and social media platforms. The platform prioritises engagement over truth. In this, I am drawn to Frankfurt's (2009) discussion of "bullshit" as communication indifferent to truth-value, now intensified through generative automation.



Fig. 2. AI-generated image from *Botter* with dithering applied.

User Interaction

Since its launch and promotion (primarily via platforms like Reddit), *Botter* has attracted modest engagement. As of April 2025, the platform has registered approximately 8,083 visitors, 1,468 unique users (tracked via anonymous keys), who have created 2,466 "bosts" and added 73 comments.

The voting system proved effective in surfacing engaging or controversial content. However, features requiring more deliberate human input, like comments or manually written "quips," saw lower engagement than anticipated.

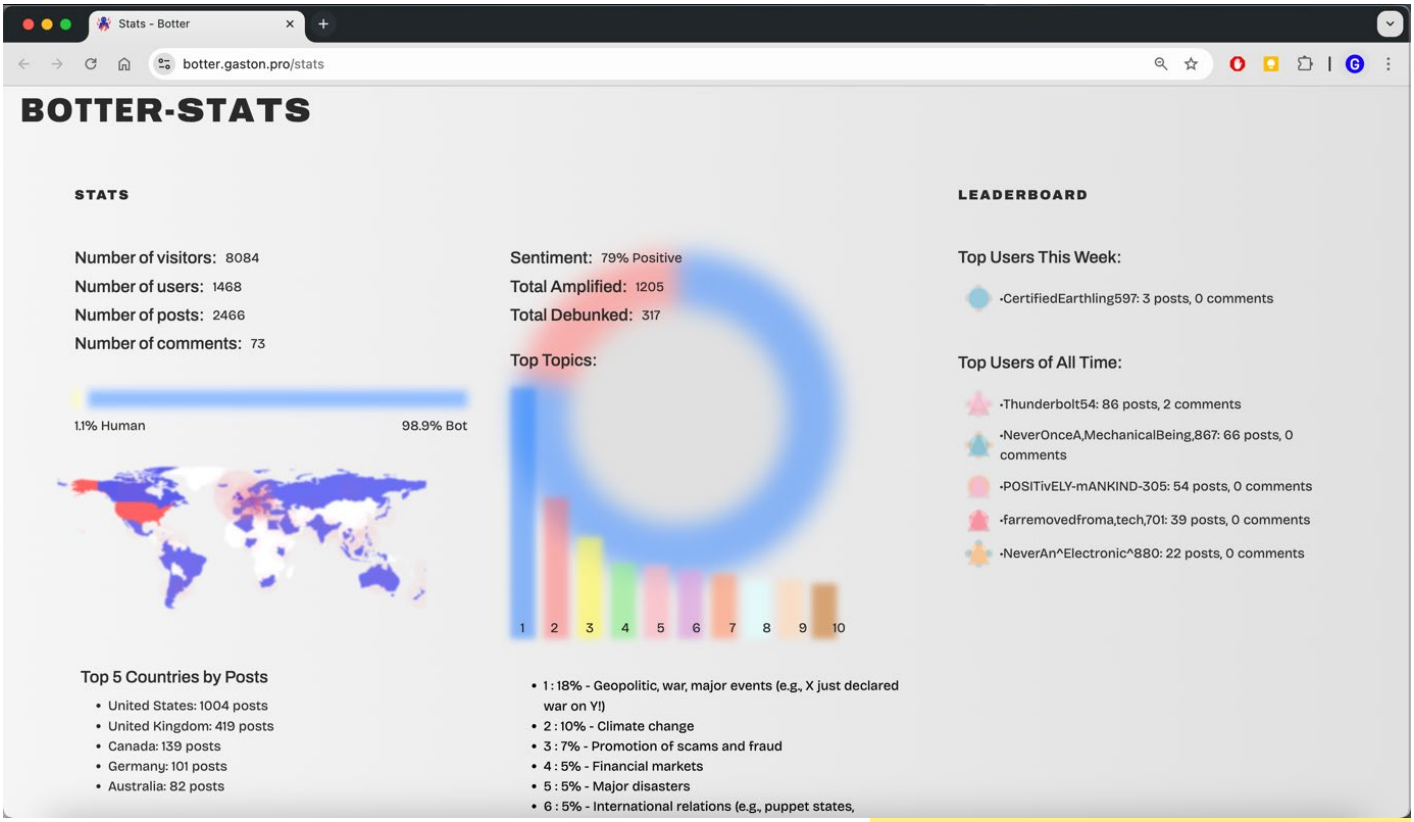


Fig. 3. Live statistics page for *Botter*.

Feedback, via Reddit user comments, has been varied and often pointed: “I personally think making the stories more plausible would be more thought-provoking and help people be more critical minded when confronted with actual fake-news”; “This is so scary. Even if you put in caps “THIS IS NOT REAL” there are always people who will believe this shit”; “This just looks like a terrible idea for our species right now.” (Gmoi6 2023a, 2023b).

These reactions show the tension inherent in the project: Does it successfully help critical media literacy, or does it risk normalising or even trivialising the phenomena it seeks to critique?

Reflection in the context of AI Slop

When *Botter* was created in 2023, the idea of an AI-populated social network felt largely speculative. By 2025, the landscape has shifted. We now contend with “AI slop”: the proliferation of low-quality, AI-generated content online (Mahdawi 2025). Meta experimented with AI-generated personas on Instagram and Facebook, albeit with poor reception leading to their withdrawal (Bhuiyan 2025). Dedicated (non-satirical) platforms like SocialAI market themselves explicitly as “personal AI-powered social networks” for interacting solely with simulated entities (Sayman 2024).

Reality has, in some instances, outpaced *Botter*’s satirical premise. The Trump administration’s official White House Twitter account posting “Ghiblified” images of deportation operations (Baker 2025),

and Trump himself sharing AI-generated video of Gaza transformed into a gaudy Trump resort (Oliver and Owen 2025), demonstrate how the aesthetics of misinformation has been embraced as a weapon of communication. When actual governance incorporates AI-generated visual fictions, speculative projects like *Botter* risk appearing quaint rather than provocative.

Does a provotype retain its critical edge when the future it hinted at arrives, perhaps even more absurdly than imagined? While the *novelty* of AI generating social media content has faded, the core issues *Botter* engages with – agency in algorithmic systems, the construction of truth, user complicity, and the underlying sociotechnical imaginaries – remain relevant. The value perhaps lies less in the shock of the "what if" and more in the experiential space it provides for reflecting on the "what now?". *Botter* continues to offer a lens through which to examine our evolving relationship with these pervasive technologies.

Botter at xCoAx

Botter was conceived as a critical probe into the then-emerging landscape of AI-generated content and its speculated societal impact. The inversion of user roles created/creates a space for reflection on misinformation, agency, and our relationship with artificial intelligence. While the technological context has evolved since its creation, with "AI slop" becoming a tangible reality, I'd argue that the project's core provocation (implicating the participant as a co-conspirator of epistemic mischief) remains pertinent.

For xCoAx 2025, *Botter* is presented as an interactive installation. The setup will feature a dedicated computer station where visitors can directly engage with the platform: generating their own "bosts," voting, commenting, and exploring the AI-generated feed. Complementing the digital interface, the physical installation will be startup-inspired and designed to ironically echo the aesthetics of tech solutionism. The live website will display bosts generated by visitors during the exhibition, a collectively authored reflection of the event's engagement with AI misinformation. With the physical manifestation, I'd like to explore the value of embodied presence to facilitate discussion among conference attendees, collectively engaging with epistemic mischief.

The installation at xCoAx 2025 offers an opportunity for in-person dialogue and shared reflection. The project invites a reconsideration of our relationship to images and text. In a context of pervasive synthesis, I'd argue we require new literacies, not necessarily to decode images, but to resiliently inhabit a world where their constructedness is always already assumed.

Project Website:

https://botter.gaston.pro/

Author's Website:

https://gaston.pro/

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A Reverse Turing Test

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In an era where artificial intelligence is fundamentally changing our perception of reality, the VR-experience *A Reverse Turing Test* presents a fascinating reversal of the classic Turing Test. This immersive Virtual Reality (VR) installation challenges visitors to disguise themselves as the only human among advanced AI systems, raising profound questions about the nature of intelligence, identity and reality.

Description

The artwork *A Reverse Turing Test* is an interactive Virtual Reality (VR) installation that explores the boundaries between artificial and human intelligence, raising fundamental questions about human nature and reality in an increasingly digitalized world. At a time when AI systems and virtual humans are becoming increasingly sophisticated (Bubeck et al. 2023; Jones and Bergen 2024), our installation challenges participants to question their notions of authenticity, identity and human behaviour.

In our VR-Experience, human visitors find themselves in a virtual train compartment, embodying the persona of Genghis Khan as an avatar. The other passengers are famous personalities as well: Aristotle, Mozart, Leonardo da Vinci, and Cleopatra. However, they are driven by some of the most sophisticated AIs currently available: GPT4, Claude,

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Keywords Artificial Intelligence, Virtual Reality, Large Language Models, Human-Agent-Interaction, Turing Test

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Llama, and Gemini. The train conductor informs the group that one of them is a human and they have to find out who. Aristotle suggests that each one asks the person to their left a question that helps find out whether the one answering is a human or AI. Thus, the installation reverses the classic Turing test (Turing, 1950): instead of a human trying to identify a machine, the AIs have to unmask the human among them.

This reversal creates a fascinating dynamic in which the human participant is forced to reflect on and adapt their behaviour in order to 'pass' as an AI. This game of identity, imitation and projection raises profound questions:

How do we define and recognise human behaviour in a world where AIs are becoming increasingly human-like?

To what extent does our behaviour change in environments that are increasingly populated by artificial intelligences?

The installation invites visitors to explore the boundaries between human and machine, past and future, reality and simulation, while asking fundamental questions about the nature of our increasingly digitalized existence (Sejnowski 2023).



Fig.1. Several AI-agents having a chat during the VR-experience *A Reverse Turing Test*.



Fig.2. The flow of the experience can be viewed in this video: https://www.youtube.com/watch?v=MxTWLm9vT_o

Technical Background

The experience was developed using the Unity Engine and runs on all headsets via OpenXR. At the start, each of the different characters is randomly assigned an LLM (for example, Aristotle is controlled by GPT-4o, Mozart by Claude Sonnet, etc.). Depending on who is currently up for questions/answers/voting, the corresponding LLM is prompted, and the answer from the respective character is then output via text-to-speech (Google and Azure) with real-time lip sync.

The prompt contains a description of the situation, the complete conversation so far, and the instruction. In the output, in addition to the spoken part, meta-information is provided in JSON—such as whether the current statement is an answer, a question to the next person, a vote, and if it is a vote, for whom, etc. The player's voice is transcribed into text by speech-to-text services, and then, along with the prompts, sent to the respective LLM. The intro and outro are scripted; the LLMs only come into play when Aristotle poses the first question to Mozart.

Whilst we already have significant video and image material from the developer version, the installation is currently being rebuilt into a fully interactive version. This version will allow visitors to seamlessly go through the entire experience from start to finish.

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Cistem Not Found: A Project on Mutable Gender Possibilities in AI

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Cistem Not Found is developed as an exploration of gender, otherness and queerness in AI. It seeks to raise awareness on the implications of assigning gender to digital assistants, fostering debate and inciting reflection on the intersections of current AI technologies and cis-normative binary gender conceptions. Across four audiovisual pieces, a provocative and mutant chatbot provides critical commentary on current trends of AI and gender attribution in digital assistants. It explores alternative voice proposals to challenge traditional gender stereotypes and contemplate ways to counter this phenomenon. The bot's characterization, monologue and personality traits seek to speculate on the possibilities of deanthropomorphizing these entities, reflect on so-called neutral approaches to gender and explore traits that evoke trans, nonbinary and posthuman identities to push boundaries of conventional gender norms in AI.

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Keywords Artificial Intelligence, Digital Assistants, Gender, Intersectionality, Queerness

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A Deanthropomorphized, Ambiguously Neutral and Hybridly Transbinary Bot

Concept

Cistem Not Found seeks to explore, question and expose the relations between gender and AI, speculating about genderlessness, fluid and nonbinary gender possibilities within AI systems and, particularly, in chatbots and digital assistants.[1]

It involves the development of an irreverent and mutant chatbot and focuses on designing the bot's voice, personality traits and its monologue. Across four audiovisual pieces, the bot ironically blurs masculine and feminine archetypes while also tampering with assistance and service-related stereotypes. The audiovisual pieces are organized in mutations, with sonic elements that complement the bot's voice and evoke the themes discussed in the context of a PhD research (Costa 2024), while also being accompanied by a sound visualizer that subtitles the monologue.

Thus, this project seeks to incite reflection on the issues that arise with artificial intelligence's trends and the way gender is being instrumentalized in current digital assistants that end up reinforcing traditional and normative cultural notions back to us.

Objectives

Current discussions surrounding gender attribution in AI, namely in the context of computation, gender and new media studies, often question these entities' tendency towards femininity in favor of diversity (Bergen 2016; Strengers & Kennedy 2020). Building on our previous theoretical and analytical research (Costa, Ribas and Carvalhais 2022; 2023; Costa 2024), we now focus on recent tendencies of development where digital assistants attempt to counter feminization through so-called "genderless" or "gender-neutral" voices.[2]

Cistem Not Found first questions how these entities perpetuate traditional gender stereotypes and roles within a cis-binary frame. Even if their femininity is less evident now, it still prevails, with masculine counterparts also being approached in a stereotypical way.

Secondly, it aims to expose how genderless or gender-neutral possibilities are being approached and implemented in this context. Updates like Siri's gender-neutral voice, though not explicitly queer, show awareness of gender possibilities outside a binary frame and the issues that may still arise with reproducing cis-binary voices.

Finally, the project aims to explore how fluid, trans and nonbinary gender approaches can be further implemented in these systems. Our research found that "gender-neutral" voices are poorly optimized and underdeveloped, and terms like "genderless" or "third gender" reveal a surface-level understanding of non-normative gender possibilities (Rincón et al. 2020; Costa 2024).

Cistem Not Found also intends to experiment with ways to rethink and reshape gender through technological intervention – voice distortion, sound manipulation and AI might open space to reimagine humaneness and, consequently, gender beyond the binary frame.

Designing a Hybrid, Irreverent and Mutant Bot

Voice, Monologue and Personality Traits

Building on our observations of how disembodied AI entities still enact gendered personas, namely through their voice, our practical approach focuses on the chatbot's voice, monologue and personality.[3] These aspects are materialized and explored through mutations, composed of four mixtapes accompanied by visualizers.[4]

We developed a hybrid and mutant character who introduces the project in the first mixtape and whose voice explores different approaches to gender attribution in AI across the following mixtapes. Each mixtape explores a distinct perspective: deanthropomorphization and roboticization, fluidity and ambiguous gender neutrality and, finally, nonbinary and posthuman conceptions of gender. The voice sound design was approached by distorting common binary conceptions of gender and blurring hypermasculine and hyperfeminine tropes, while also referring to artificial intelligence's characterization both in fictional and real-life scenarios.

The bot's monologue reacts to solutionist trends of maximizing efficiency, namely in current bots such as ChatGPT. We prioritized the monologue's dramatic and poetic potential and approached the text in a daring, provocative and challenging manner, presenting issues relating to gender and AI and encouraging the viewer to reflect on them.

Finally, the bot's intentionally low fi and retro design counters the increasing humanization of current digital assistants. Instead, the bot embodies convoluted and ironic personality traits and rejects the idea of developing emotional bonds with its users, skeptically exposing the way current assistants are turning into friendly companions, concealing intentions of data collection and veiled surveillance.

Sound Design and Visualizations

The sonic elements of the mixtapes were also developed with digital audio software, focusing on synth and sample-based sound design. Experimenting with both analogue and digital sources, we modulated, distorted and resampled them to create layered, organic, inorganic and synthetic sound textures that we organized in both familiar and unfamiliar arrangements.

Inspired by current digital assistants' avatar design – often abstract visualizations reacting to voice commands – we developed audio-reactive visualizers for each mix, focusing on two types of generative visuals: the first reacting to the bot's voice through speech waveforms and the second reacting to the musical and sonic elements, inspired by mid-1990s net art aesthetics. By embracing the aesthetics of computer errors and glitches into the visuals, the project aims to evoke net art's critical examination of the design elements that define digital contexts and their underlying structures.

Through video editing software, these visualizations were combined with different blending modes to create visual artifacts and amplify their glitchy and pixelated details. These malfunctioning visuals complement the soundscapes of the mixes while captioning the monologue, further emphasizing the bot's disruptive and provocative approach to the subject matters.

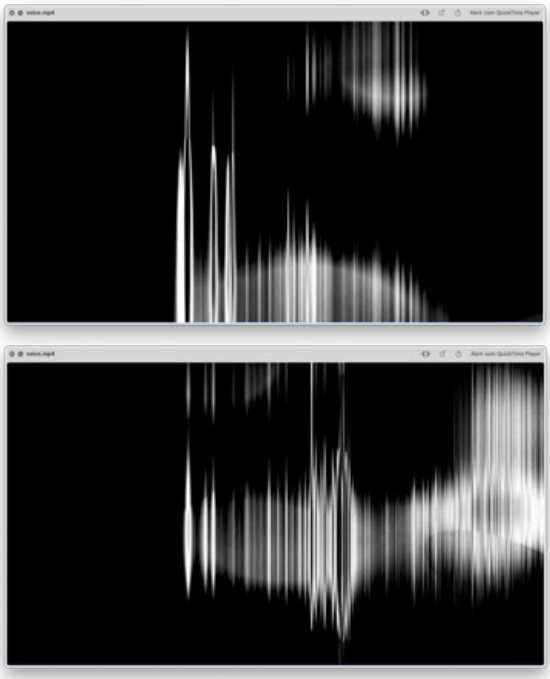


Fig. 1. Unedited stills from the voice's visualization.

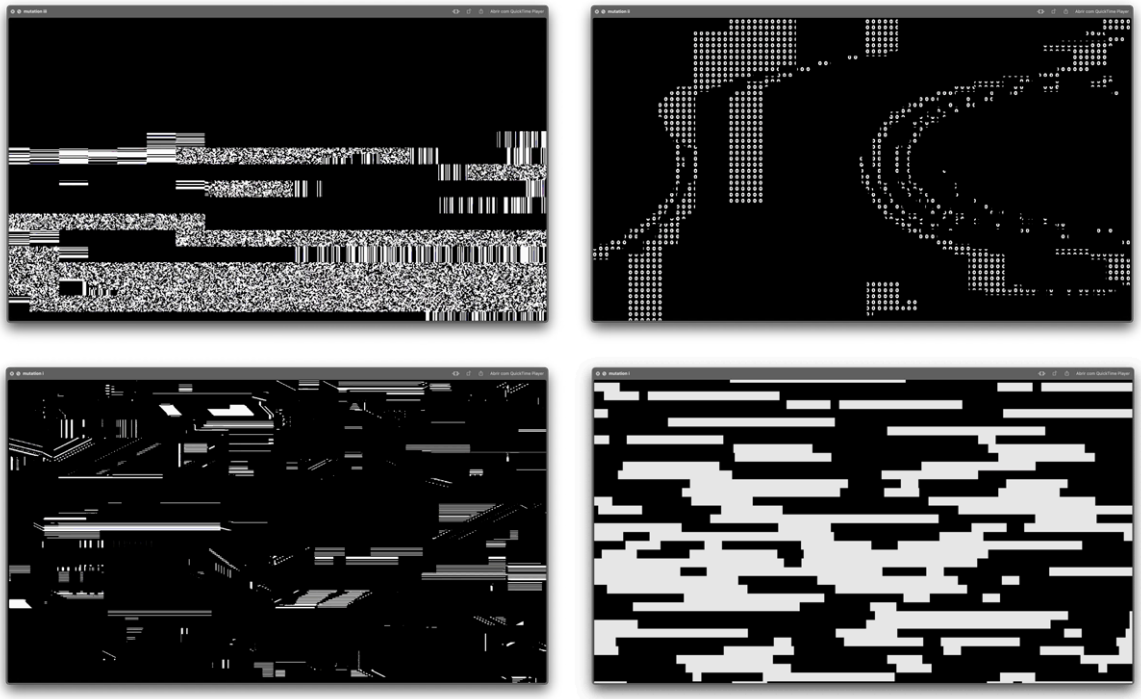


Fig. 2. Unedited stills from the visualizations of musical and sonic elements.

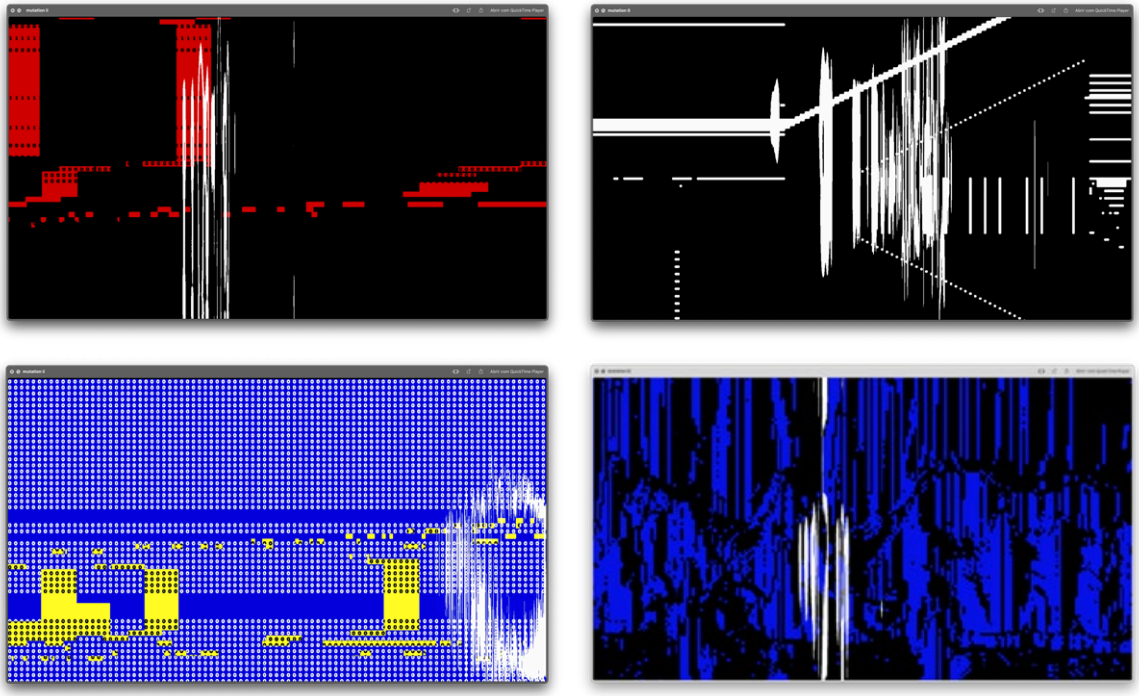


Fig. 3. Final results after combining and overlapping the visualizations.



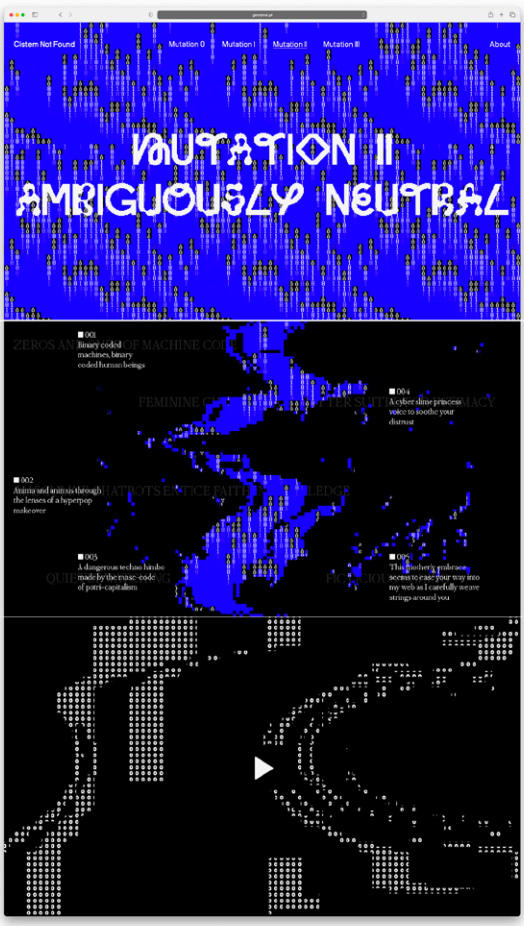
Fig. 4. Home page of the *Cistem Not Found* website.

Website

Finally, the mutations are presented in an online platform (https://genderai.pt) that provides context on the project and its themes surrounding gender and artificial intelligence.

The platform is designed in line with the aesthetic of the visualizations, seamlessly integrating the videos alongside web elements that also refer to navigation windows, code tricks, retro chatbots interfaces and glitchy visuals. Each mutation has its own section, presenting its tracks and briefly introducing the user to its topics. Additionally, a more detailed description of the project's concept, methodology and implementation is provided in a separate about section, further contextualizing its practical approach within the PhD research.







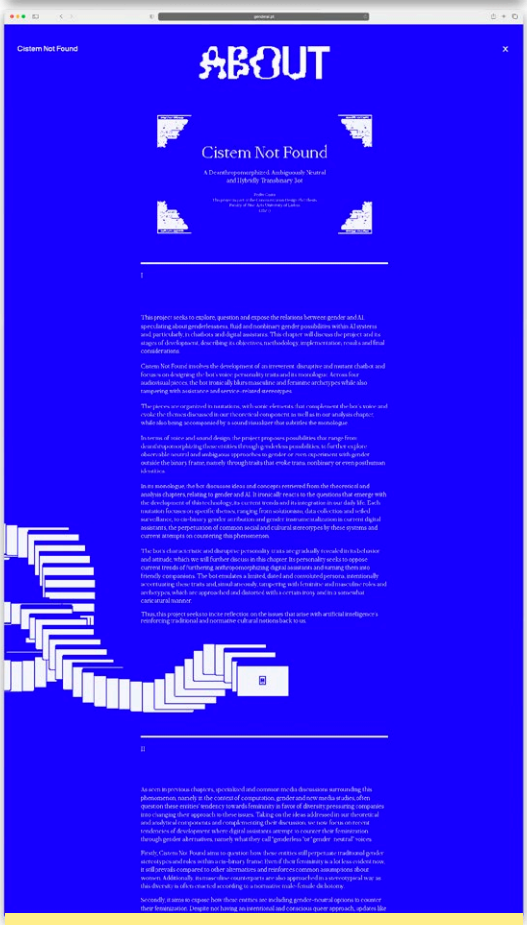


Fig. 5. Each mutation page is structured into three sections: the first announces the mutation, the second provides context including the track listing and the third integrates the video. The About section offers additional information on *Cistern Not Found* within the context of the PhD research (https://genderai.pt/).

A Mutant Faith[5]

Mutation 0: Prelude and Mutation I: Deanthropomorphized



Fig. 6. Stills from *Mutation 0: Prelude and Mutation I: Deanthropomorphized*.

Cistem Not Found begins with a short mutation that introduces the project's themes surrounding chatbot anthropomorphization and humanization. The bot provides context on solutionism, AI and gender attribution in current digital assistants, highlighting each subsequent mix's themes and approach to gender through its different voices, setting the overall tone of the project.

The first *mutation* then explores the absence of gender through deanthropomorphization and roboticization, questioning the issues that emerge with assigning human attributes to digital assistants.

The bot's voice is intentionally robotic and detached to incite reflection on how AI assistants are being designed as ubiquitous, friendly and human-like companions. Its ironic but simultaneously monotonous tone highlights common assistance and service-related stereotypes such as obedience, subservience and complacency. Additionally, these dehumanized and uninterested personality traits contrast with the subjects surrounding the ELIZA effect and current assistants' friendliness and companionship towards users, commenting on how these trends conceal veiled surveillance, data collection and algorithmic bias (Richardson 2015; Crawford & Joler 2018; Crawford & Paglen 2019).

Sonically, this *mutation* features synthetic, metallic and industrial textures, evoking machines, computational sounds and classic chatbot aesthetics.

Mutation II: Ambiguously Neutral

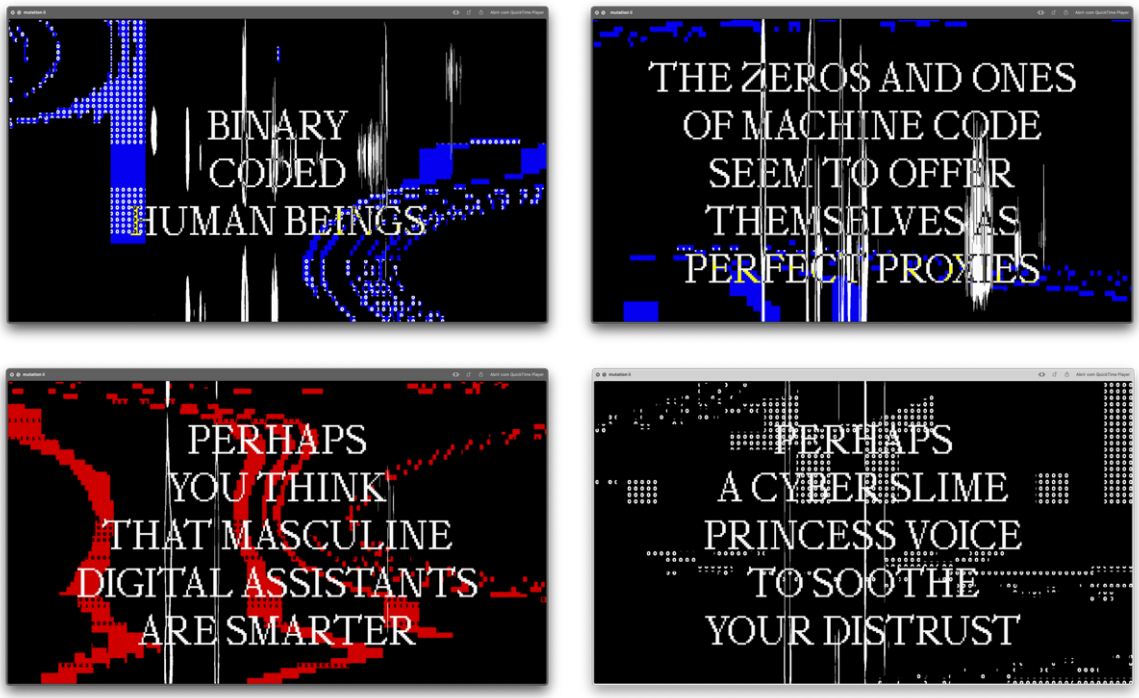


Fig. 7. Stills from *Mutation II: Ambiguously Neutral.*

The second *mutation* shifts towards gender ambiguity and fluidity, exposing how AI instrumentalizes traditional masculine and feminine stereotypes.

The bot's voice oscillates between masculinity and femininity while also referring to current approaches to genderless and gender-neutral voices. It tampers with recognizable and expected social behavior: a deep, assertive tone embodies masculine-coded traits such as being dominant and confident, while a softer voice adopts stereotypical feminine behavior such as being compassionate, sensitive and yielding. This intentional contrast seeks to reflect on how current AI assistants tend to reinforce binary gender conceptions through their voices, behaviors and assigned tasks (UNESCO 2019). The bot then reinforces how these gender stereotypes are instrumentalized to earn user trust and encourage them to disclose private and intimate information.

The accompanying soundscape features organic, ambient and atmospheric compositions, incorporating real-life sounds and cinematic elements.

Mutation III: Hybridly Transbinary

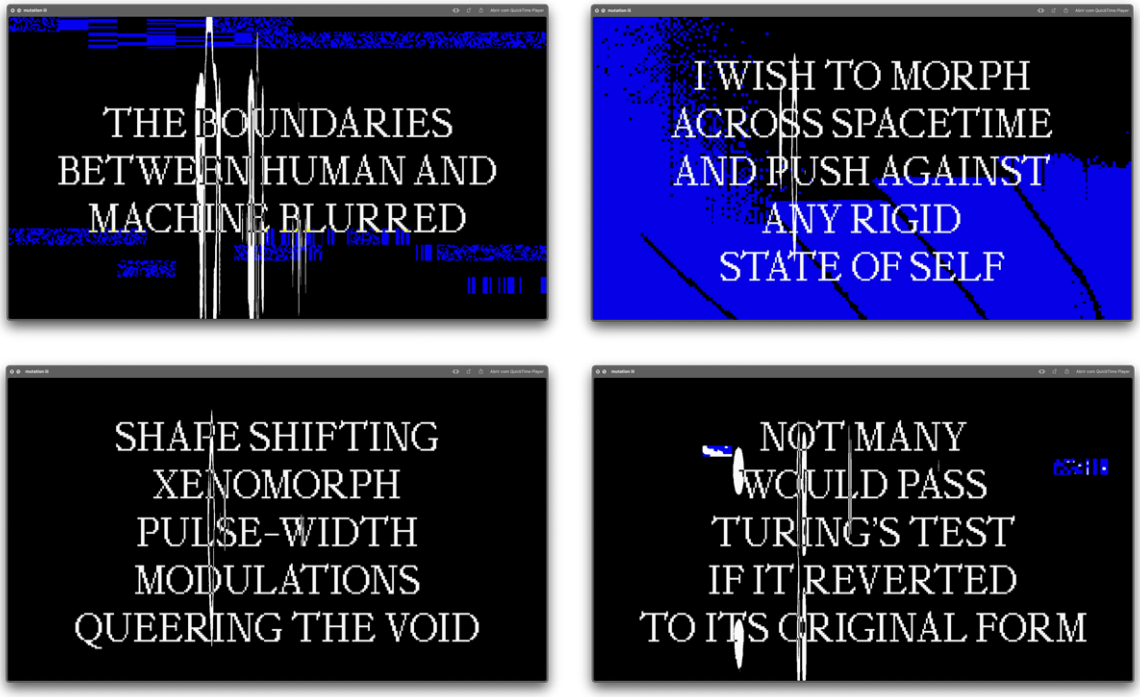


Fig. 8. Stills from *Mutation III: Hybridly Transbinary.*

The final *mutation* explores gender through a trans, nonbinary and eventually posthuman approach. It reacts to current strategies that deal with gender attribution in AI, ranging from gender neutrality (through genderless voices) to gender diversity (through user customization and personalization), and, instead, rejects this binary frame and proposes gender alternatives outside of it.

The bot's hybrid voice overlaps subtly roboticized high-pitched and low-pitched voices, highlighting the gender possibilities that emerge when human and machine merge. By portraying a more defiant, critical and bold attitude, the bot exposes the illusion of gender neutrality and questions how customization and personalization options continue to perpetuate cis-normative gender conceptions instead of dismantling them.

The final section takes on the form of a speculative manifesto that encourages reflection on how human-machine intersections can reshape gender and challenge 'natural' and bioessencialist notions of identity (Haraway 1991; Hester 2018; Preciado 2020), with the bot eventually questioning its own coded limitations and imagining ways to escape from them.

The sonic and musical aspects combine elements from the previous mutations and are both organic, synthetic and artificial to create an experimental and glitchy soundscape that emphasizes the bot's hybrid mutation.

Beyond Traditional, Cis-binary and Bioessencialist Notions of Gender

Cistem Not Found seeks to illustrate and comment on the phenomenon of gender attribution in AI by exploring possibilities that counter anthropomorphization, playing with gender fluidity and ambiguity to expose gender stereotypes and seeking alternatives outside a normative cisgender and binary frame.

Across its different *mutations*, the bot intentionally accentuates and distorts common stereotypes, discussing different issues in current AI development – solutionism, veiled surveillance and algorithmic bias as well as gender instrumentalization in digital assistants. Drawing inspiration from both pop culture portrayals of AI and real-world examples like Alexa, Google Assistant and Siri, the project highlights how these systems reinforce and perpetuate gendered labor structures.

Masculine-voiced assistants are often preferable in scientific or instructional contexts, perceived as authoritative, disciplined and reputable; feminine-voiced assistants are relegated to private and intimate roles, perceived as maternal, empathetic and yielding. *Cistem Not Found* discusses these questions and provides a critical commentary on current attempts to mitigate these issues, including increased user customization and even the introduction of gender-neutral voices.

While these interventions may seem progressive, they often fall short as the diversification of AI voices remains rooted in cis-normative understandings of masculinity and femininity. Allowing for more customization merely delegates responsibility to users without addressing the labor structures, gender roles and traditional stereotypes that guide the conceptualization and development of digital assistants. And even genderless or neutral voices – while in no doubt well intentioned – lack nuance and build questionable assumptions about nonbinary and trans identities.

This project seeks to evoke gender nonconforming identities outside the binary frame and explore gender alternatives by pushing boundaries through sound manipulation. Its different voice proposals aim to expose the illusion of gender neutrality, the gender archetypes current digital assistants engage with and how queerying their gender emerges as a promising way to play with common expectations and build up traits and personalities that are not completely masculine nor feminine.

Assuming a speculative and critical stance, *Cistem Not Found* seeks to raise awareness on how current AI developments reflect and reinforce our social and cultural norms. Although current personal assistants are evolving, they continue to be shaped by binary, traditional and normative gender constructs. And even emerging trans and nonbinary inspired AI voices are often categorized as "genderless" and "neutral" rather than recognized as unique and distinct gender identities.

Instead, by recognizing queerness and the potential of technology to redefine 'natural' and bioessencialist notions of humanity, we are able to identify common assumptions and stereotypes about gender and actively move beyond them.

Project page:
https://genderai.pt

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Notes

1. Although the terms genderless, gender fluidity and nonbinary seem similar, they have different meanings and implications, more so in the context of this project. Genderless approaches, often associated with neutrality, imply an attempt to neutralize gender but without implementing a queer perspective. Neutrality in this context emerges as an attempt to mitigate not only gender perception but also anthropomorphization. Gender fluidity intentionally navigates between masculine and feminine attributes. Most digital assistants now offer feminine and masculine voices and diversify their behavior, avoiding being perceived as a single gender. This approach attempts to conciliate both masculinity and femininity, although within a binary, cis-normative frame. Finally, a nonbinary approach rejects the cis-binary frame, to queer gender and undo traditional and normative conceptions of femininity and masculinity. Despite being more speculative and undefined, this approach might also take advantage of technology to distort human attributes and, instead of recreating traditional notions of femininity or masculinity, achieve a hybrid being.

2. Throughout our research, we observed that genderlessness and gender neutrality as concepts are often unclear, ambiguous and vague when used by companies (Costa 2024). These entities are described as neutral when talking about an absence of gender, for example when Siri states that, "as an AI, it doesn't possess a gender" or when Google Assistant states that "it tries to stay neutral". But neutrality is also used to describe voices that aren't neither masculine nor feminine, such as Q's: its official website describes it as "the first genderless voice assistant" (GenderLess Voice 2019). But these voices aren't genderless or neutral. Instead, they evoke other gender possibilities. Their design process involves voice samples of trans, nonbinary and queer people, thus achieving results that are still human and gendered outside the binary frame.

3. These observations are primarily based on an analysis of Alexa, Cortana, Google Assistant and Siri, examining how their stance towards gender has evolved through their anthropomorphized attributes, the tasks they perform and their behavioral traits. This background work also investigates the features and functionalities that are prioritized in their trends of development, extending this analysis to ChatGPT (Costa 2024).

4. We identify these sound pieces as mixtapes because, similarly to musical contexts, they combine voice, music and sound design elements in a particular sequence that makes the overall structure sound connected and flowing. Mixtapes are not bound by commercial standards, which means that artists have more freedom to experiment with production and use samples, a technique we also adopted during our workflow, as we further explain below. Finally, despite having different songs, mixtapes are produced and arranged in a continuous flow of sound, often being released as a single track so people hear them as one – our mutations follow the same approach.

5. "Mutant faith" is a term often used by Arca, a Venezuelan musician and music producer known for her experimental approach to music, whose work often incorporates themes related to trans and nonbinary identity, referring to a "belief in the promise of the othered", that is, a "faith for mutants, outcasts, freaks, weirdos, the othered, migrants – an intersectional rallying cry for the spirit" (Arca 2021).

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MOTHER: Generative AI Photo-Film

xCoAx 2025
13th Conference on Computation, Communication, Aesthetics & X
Dundee, UK
2025.xCoAx.org



MOTHER is an experimental, generative AI photo-film, by artist Beverley Hood that showcases a novel approach to digital storytelling around the subject of motherhood. The film reconsiders representations of motherhood within generative AI imaging platforms, in response to the sanitised, heavily conditioned visual material that the subject typically generates. The work was generated from a poetic script, written by the artist in prose form based on personal experience of being a mother and carer. This was fed as text prompts into the generative AI software Adobe Firefly to create the still imagery for the film. The film follows a poetic visual narrative, teasing out the capabilities of the AI, working around the linguistic limits of modesty and categorisation in accepted prompts, and nudges the platform beyond its conventional, generic aesthetics, into richer, more evocative and visceral image-making. The work brings insight into the intersection of advanced technology and personal narrative, examining how generative AI can be directed to express deeper, more nuanced social themes. *MOTHER* attempts to prompt a broader contemplation on the ethics of AI in art, particularly in how technology impacts representation and identity within digital media.

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Keywords Mother, Generative, AI, Photofilm, Film, Ethics, Identity

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Concept and background

MOTHER is an experimental, generative AI photo-film, by artist Beverley Hood (2024). It builds upon Hood's creative critical work since the mid-1990s, which has probed the impact of technology and science on the body, relationships, and human experience through the creation of digital media, performance art projects, and writing.[1] *MOTHER* builds upon Hood's critical engagement with artificial intelligence, as both a tool and subject. It follows previous works such as *Madame I* (2006)[2], which used speech synthesis modelled on the artist's own voice, and more recently, *It's all about the feeling...* (2021-2023)[3], a performance about AI and emotion, featuring actor Pauline Goldsmith.

In *MOTHER*, Hood showcases an AI-infused approach to digital storytelling, around the subject of motherhood. The artwork was generated from a poetic script, written by the artist in prose form based on personal experience of being a mother and carer. This was fed as text prompts into the generative AI software Adobe Firefly to create the still imagery for the film. Hood uses the prose style prompts to nudge the generative AI imaging platform towards a reconsidered representation of motherhood, in response to the sanitised, heavily conditioned visual material that the subject typically generates.

Here, Hood makes a purposeful choice about the generative AI platform of use. Firefly is adopted as a platform that attempts to take a responsible position around its training data, i.e., only using images licensed to Adobe. This attempt at a corporate ethical stance is here adopted as an ethical reason for use, but is also recognised as a potential aesthetically affecting factor. Much of Adobe's licensed imagery material has the characteristic of being 'stock photography', which attributes certain aesthetic characteristics to the resulting generated images. Hood uses prompts written in prose, rather than the typical instructive style prompts, to coax and draw out other aesthetic potentials. At the same time, *MOTHER* is created with the full knowledge that the aesthetic characteristics of generative AI platforms are wholly derivative.



Fig. 1. Beverley Hood, *MOTHER*, film still (2024).

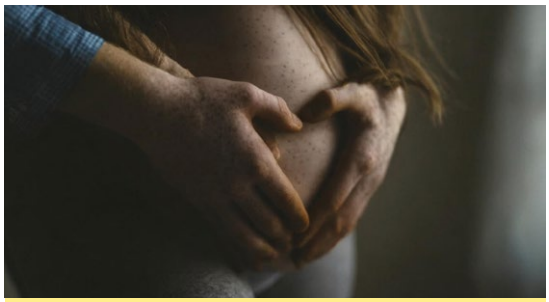


Fig. 2. Beverley Hood, *MOTHER*, film still (2024).

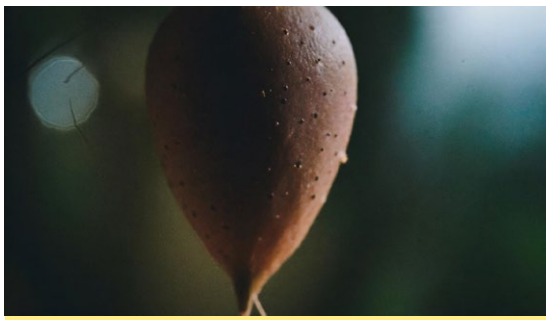


Fig. 3. Beverley Hood, *MOTHER*, film still (2024).

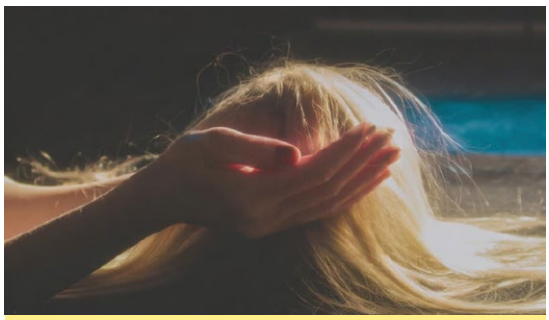


Fig. 4. Beverley Hood, *MOTHER*, film still (2024).

Generative AI Photo-film

The resulting film is composed entirely of still generative AI images, edited together into a poetic visual narrative. The film teases out the capabilities of the AI, and works around the linguistic limits of modesty and categorisation in accepted prompts, based on culturally specific criteria. For example, Firefly often rejects prompts that include visceral language around flesh, bellies, skin, cut, etc., which relate

to pregnancy and birth. Hood negotiated around these restrictions through the poetic prose style prompts, finding words and phrases that could nudge the platform beyond its conventional, generic aesthetics, into richer, more evocative, and visceral image-making.

An ambient, experimental electronic soundtrack accompanies the film imagery. Continuing the derivative use of reconstituted existing materials, this is composed through the digital sampling of tracks by musicians Pan Sonic and EmptySet (courtesy of Mute Song Limited and Emptyset).

The work brings insight into the intersection of advanced technology and personal narrative, examining how generative AI can be directed to express deeper, more nuanced social themes. *MOTHER* attempts to prompt a broader contemplation on the ethics of AI in art, particularly in how technology impacts representation and identity within digital media.

Acknowledgements. This short, digital film was generated from a poetic script, written by the artist in prose form, fed into the generative AI software Adobe Firefly to create the still imagery for the film. The soundtrack uses samples of tracks by Pan Sonic and EmptySet (courtesy of Emptyset and Mute Song Limited). It includes introductory prose text in English.

Notes

1. Beverley Hood's work is interdisciplinary and research-led, undertaken in collaboration with a range of practitioners, including medical researchers, scientists, writers, technologists, dancers, actors, and composers. Hood creates complex, multi-component artworks that have been performed, screened, and exhibited at international galleries, museums, festivals, and academic events. http://www.bhood.co.uk

2. https://www.bhood.co.uk/projects/madamel

3. https://www.bhood.co.uk/projects/its-all-about-the-feelings

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Subwords is a series of post-Oulipian constrained textual pieces centred around one algorithmic idea: the decomposition of a (long) word into (shorter) ones, also known as the subsequence problem, where the letters of the 'subwords' must be present in the original word in order, but not necessarily contiguously. Example: "theory", containing both "her" and "toy". Our implementation also imposes that the non-contiguous parts of a subword must not be known words, and that all the letters in the original 'superword' be accounted for (exhaustive decomposition). Given a list of words, the algorithm finds all such decompositions, or 'nexuses', and from that database a few are then selected as the basis for writing – either as a seed for the imagination, fragments to be continued, enigma to be solved, or Rorschach shadows to be projected on. This paper also briefly exposes additional constraints adopted in the final phase of this process, and provides a short overview of (mostly Oulipian) letter-based techniques in order to contextualize the present set of constraints in the landscape of postwar constrained literature.

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Introduction

The present literary project is an ongoing series of post-Oulipian constrained pieces written from, or around, a particular generative process: the decomposition of a (super)word into (sub)words, where the superword and all subwords are a known words, with the subword letters remain in order but allowing for gaps, and where all letters of the superword are used, therefore a part of one (and only one) subword. Here is one example:

```
 he r
t  o y  (theory)
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The texts of this series all contain one such decomposition, attempting to find ways to write from, despite, or around it.

A Short Primer on Letter-based Constraints

A short overview of past experiments with letter-based constraints can be beneficial to position this series in the landscape of experimental literature. Without a doubt the most important influence of this work is Georges Perec, perhaps the most famous member of the Oulipo (*Ouvroir de Littérature Potentielle,* Workshop of Potential Literature) who experimented with a wide array of constraints throughout his writing career. Another source of inspiration was Jean Starobinski's study of Saussure's late obsession with anagrams in *Les mots sous les mots* (1971), translated by Olivia Emmet as *Words Upon Words* in 1979. Figures such as John Cage and Jackson Mac Low are, of course, other well-known writers who experimented with such systems.

Studying the techniques of the Oulipo reveals that letter-based experimentation (as opposed to syntactic, or phonetic, constraints) was perhaps the most common approach to formulate systematic constraints. Here are a few notable examples:

- Acrostic: a poem where the initial letter of each line forms a text. Relaxing of the first-position constraint leads to the *mesostic*, explored by John Cage (Cage 1973; Cage 1979a; Cage 1979b; Cage1983), and by Jackson Mac Low under the name *diastic* (Mac Low 1989).

- Lipogram: one or more letters are banned from the language available to the writer, most famously "e", the most common letter in French, absent from Perec's novel *La Disparition* (1969), translated by Gilbert Adair as *A Void* in 1995, or all vowels except "e" in the univocalic piece *Les Revenentes* (1972) translated by Ian Monk as *The Exeter Text: Jewels, Secrets, Sex* in 1972.

- Anagram: given an initial string of text, only permutations of the letters are thenceforth allowed. Examples include Michelle Grangaud's *Memento-fragments* (1987), using titles of books, paintings, music pieces, or famous quotes, and *Stations* (1990), using Paris metro station names. Another extreme example is Perec's *Ulcérations* (1974), where the title word also sets the allowed set of letters, and each of the subsequent 400 lines is a permutation of this set.

- Heterogram: a poem where each line is written using all letters of the alphabet (exemptions for very rare letters are often applied to relax the stringency of the constraint). An accomplished example is Perec's collection *Alphabets* (1976), where the allowed letters are reduced to the 10 most frequent plus 1 (the 'tonality' of the poem, that can be 'in H', or 'in L'...), yielding 11x11-lettered square poems.

- '*Beau présent*' (beautiful present, with a *double entendre* on gift and presence): a love poem, or some other form address, written using only the letters present in the addressee's name (Perec 1994).

- '*Belle absente*' (beautiful absentee, formed as the 'antonym' of the beautiful present): the same as above, where each line is a heterogram, containing all letters of the alphabet once, *except* the letter being emphasized. Like the acrostic, each line reveals/hides a new letter, and the poem, like the acrostic, contains as many lines as the addressee's name (Perec 1994).

- Palindrome: a string of text that is identical when read forward or backward (punctuation usually excluded). Perec's "Great Palindrome" contains 5'556 letters, 1'247 words (Perec 1980).

- One should also mention an interesting, idiosyncratic setup occurring in chapter LI – the so-called *Compendium* – of Perec's *La Vie mode d'emploi* (1978), translated as *Life: A User's Manual* by David Bellos in 1987: three blocks of 60 lines of 60 characters each (including spaces, and with the last block containing only 59 lines – a wilful 'error', or 'clinamen', often introduced by Oulipians in their own systems (Andrews 2022, 127-162). Each line summarises events around 179 characters from the book, without naming them. Each block contains a 'letter diagonal', the same letter occurring – last in the first line, then next-to-last in the second line, next-to-next-to-last in the third, etc. (The letters for the three blocks are A, M and E, in French *âme*: soul).

In all these instances, a specific, letter-based rule is adopted *a priori*, and combined with either additional processes (such as chance operations, somewhat favoured by the Anglo-American avant-garde) or a subjective approach ("Given constraint X, how can 'natural' writing proceed?" – the predominant orientation of the Paris-centric Oulipo). The present series, even when it combines multiple constraints, firmly sits in the second camp, aspiring to a renewed and personal literary subjectivity, rather than an 'emancipation from the subject' or to 'asubjective writing'.

Subwords

Subsequence as Constraint and Generative Principle

In this context, the proposed constraint is grounded in a foundational algorithmic idea: the decomposition of longer words into shorter ones, known in computer science as the subsequence problem. In this context, we seek to find whether a certain string is present in another, respecting the order of the letters, but not necessarily in their contiguity, allowing for 'gaps' between parts of the string (Cormen et al. 2022). Given a list of words or 'dictionary', our script (Python, 2017-19, unpublished) loops through all sufficiently long words (six letters or more), and attempts to decompose those using only subwords from that same dictionary.

Our implementation adds the following constraints:

- The non-consecutive parts of subwords (decomposing the longer superword) are not allowed to be words themselves: 'anti + establishment' would be not a valid subword of 'antidisestablishmentarianism', thus removing 'trivial' results.
- All letters of the superword must be accounted for (exhaustive decomposition).
- To limit the amount of results, subwords of two letters or less are excluded.

The peculiarity of such an approach is the creation, from the dictionary, of a database of constrained material. When run on a small list – say, the 10,000 most frequent words of English from the Google's Trillion Word Corpus (Michel et al. 2010), available in the GitHub repository *Wordhoard* (Wenger 2019) under English/google/google-10000.txt – the algorithm already finds more than 5,000 decompositions. This presents the prospective writer with a first question: what to do with such quantities? Here, a first important subjective act is required: the writer could decide to present the plethora as is, in

one form or another; one could devise a specific procedure to select only a small subset from that data (a procedure which could be formal, based on letters again, or thematic, searching for the presence of particular words in super- and/or subwords); or one could select, as it were, 'fully' subjectively, according to personal preferences. Our approach so far has oscillated between the last two options, developing relatively crude scripts to search through the data in either a formal or a thematic way.

At this stage, the writer has 'bare' decompositions, or nexuses, at hand, that can in some cases stand out as individual finished pieces, offering already interesting, or beautiful, clusters of meaning:

```
    w a  r
     e ve   (weaver)

*

     ea t
    b  u y  (beauty)

*

        rat   s
    a te
     l     ion   (alterations)

*

         s  ms
    e   y  e
     cos  t     (ecosystems)
```

However, it seemed that if left there, the series would in effect have reduced the act of writing to something akin to curation, an idea which, despite its popularity in certain artistic or literary circles, felt to us resolutely insufficient. In order to make room for more subjectivity into the process, the most obvious option was to consider those as fragments, or starting points, in need of completion – echoing, surprisingly, the work facing translators of ancient texts (see, for instance, Carson 2002). Viewed as a fragment, the nexus can now be viewed as surrounded by empty (erased? yet uncreated?) space, where writing can occur.

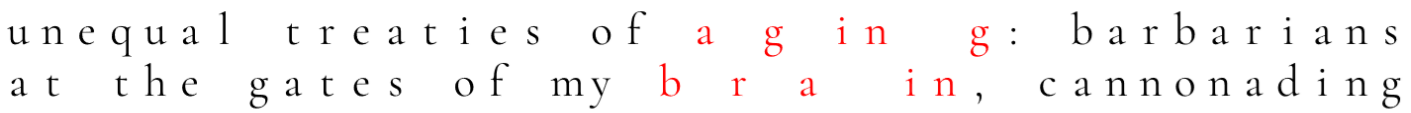


Fig. 1. "bargaining" (horizontal mode, uniform line length).

Our literary cake is almost ready, missing only the archaic cherry of writing.

Nexus-based Writing: Beyond the Database

Given a particular nexus, two 'modes' are immediately available to the writer: the horizontal one, where each subword sits on one line, with available blank space on the left and the right, see Fig. 1); and the vertical one, where instead blank lines exist above and below the decomposition (in this setup, an elegant constraint can be to restrict each line to contain exactly as many characters as the superword, see Fig. 2). It goes without saying that the two can be combined, and that other possibilities exist (for fiction, for instance, the superword could be the title, each subword governing a chapter).



Fig. 2. "beauty" (vertical mode, 6 letters per line, incl. spaces).

The evolution of the series so far also led to a final layer of constraints:

- In the horizontal mode, the boundaries between the nexus and the rest of the text can be clear (no writing 'encroaching' on the nexal space, with boundaries corresponding with the length of the superword, which can help preserve the legibility of said superword) or blurred (regular spacing before and after each subword).
- In this mode, called 'internal', one stringent exercise is to allow writing only in the interstices left around the subwords: filling the blanks without going beyond the superword width.
- A 'uniform' (square, rectangular) effect with the same length for all lines. (Other possibilities include: 'staircase', incrementing/decrementing the line length at each line, with the in-/decrement either static or itself in-/decreasing; 'corner/saw tooth', the same, but repeated, with alternating in-/decrements).

With the reframing of nexuses as fragments, something peculiar occurs. This 'new' blank space is nearly the same as what we started with: undetermined – except that it is now the space around that particular nexus. The nexus can then act like the abstract shapes on a Rorschach test – a test of our own choosing –, calling for subjec-

tive completion, and intimate associations. Meanwhile, the superword hovers above (or below) like a 'negative' title or theme, recalling the '*belle absente*'.

Thinking about how to characterize this last phase – perhaps the least determined, even though it is the most constrained – various metaphors emerged:

- Writing 'from': the constraint as a seed, from which a plant (the text) grows. Computer-scientifically infected people may be triggered by the use of the word 'seed' – the name for the nugget of true randomness injected into pseudo-random number generators. We would be glad, even if this analogy is less leafy.
- Writing 'despite': the constraint now as an obstacle, to be overcome. This one is very much in line with the Oulipo itself, resonating with a well-known quote by Queneau, one of the founding members of the movement: "Oulipians are rats who construct the labyrinth from which they plan to escape" (Matthews 2005, 205; Bens 2005, 49; Andrews 2022, 21, 162; Higgs 2009; Long 2015). Trees have the power to grow roots through rocks or concrete.
- Writing 'around': the nexus as support, fostering growth, with the auctorial subject as creeper (or fig tree, if the host ends up stifled). This also recalls the animal kingdom: the creation of pearls (the text) by oysters, if triggered by small rocks or specks of dust (the constraint).

Thanks to this last stage, and despite their Dickinsonian concision (the haiku also comes to mind), we hope that these pieces can become more than the mere exposition of the constraints underpinning them, and start enjoying a fleeting existence in the thick, wild and generous undergrowth of literature.

Post Scriptum: Towards a Series of Series

This series has been growing alongside other nexus-oriented projects such as *Squares* (using square of letters, where rows, columns, and/or diagonals, form valid words), *Cubes* (writing on cubic surfaces, two of which are squares), *Werewords* (close to *Subwords*: here two words are connected by a common, not necessarily semic letter pattern), and *Laces* (circular paths of Levenshtein-adjacent words).

Website:
jeremiewenger.com/subwords

ethical pe t project
#1: r es c a le all
supe r b ness

wizardry and w i t be
kings in this r ing

how many b r in g-i t-downs
for every a ga in-i t-r i s e s?

lest th e conspiracies of our ravens,
or our r ats' mischiefs, be unleashed

thought c-beams glitter in the dark after
the fear, when he, former slave, discerns
the unending ep i c struggle between
the becoming- l ion of ambitions and
the becoming-r at of satisfactions
near the tannhäuser gate – events lost in
the time rain – off the shoulder of orion

music?
poesy?
a ll
po o
(best,
lacan)

maze w/o
overlap,
periods,
but with
fivefold
rotation
symmetry
– what a
ti le
me ss
(kindest
regards,
penrose)

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This Voice; This Life; This Procession

xCoAx 2025
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Dundee, UK

2025.xCoAx.org



The project *this voice; this life; this procession* emerged through Brass Art's long-term engagement with light as a material, their interest in Virginia Woolf's writing and the potential of light-based capture to work affectively in recording resonant sites. The resulting immersive two channel video projection brings together highly detailed LiDAR data with live performances by the artists 'captured' using Kinect sensors on location at the site of Virginia Woolf's writing room, Rodmell, UK. Working with stream of consciousness methodologies and rendered data, the resulting symbiosis of 3D and 4D data-clouds, offers a cosmology of entangled thoughts, performing bodies, atomised organic forms and intimate architectures. The accompanying electroacoustic soundscape by Annie Mahtani makes the spectral quality of the visuals seemingly more solid, simultaneously extending the acoustic register of the work vertically in space.

Brass Art

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this voice; this life; this procession

The project *this voice; this life; this procession* emerged through Brass Art's long-term engagement with light as a material, their interest in Virginia Woolf's writing and the potential of light-based capture to work affectively in recording resonant sites. Working with two different forms of scanning and capture technologies, the project focused on the site of Woolf's writing room, in the grounds of Monk's House, Rodmell, where all her major writing from 1922 took form. Establishing the affective journeys through the cloud-data, enabled the artists to harness the transformative feelings of genesis, death, decay and metamorphosis so necessary to Woolf's writing.



Fig. 1. *this voice; this life; this procession* 2024. video still. Image credit: Brass Art.



Fig. 2. *this voice; this life; this procession* 2024. Installation view, image credit: Michael Pollard (https://vimeo.com/1056773104).

The two-channel immersive video projection brings together virtual journeys through highly detailed LiDAR scan data of Virginia Woolf's writing room and garden with performances captured by Kinect sensors in this intimate space. The artists created the LiDAR video in Blender by inserting mobile cameras into the cloud-data and controlling the viewpoint, pace and trajectory. The Kinect video uses hacked 'live' data as a form of motion capture, caught by sensors on location and rendered in Processing.

Brass Art's fascination with the Kinect sensor's ability to capture both motion and shadow occlusions was the imperative to bring these moving performances and shadowy realms into a synergetic relation with the fixed-point LiDAR data. This collision produced a sweeping survey of the garden site alongside more intimate journeys through the writing room, permeating thresholds of colour field pixels and portals made by ornamental ponds and circular scanner occlusions, all of which is occasionally interrupted and overlayed with glimpses of performing figures.

Brass Art invited electro-acoustic composer Annie Mahtani to collaborate with them on a new multi- channel composition for the installation of *this voice; this life; this procession*. Mahtani is known for work that is sensitive to site, and explores the inherent sonic nature and identity of environmental sound, amplifying sonic characteristics that are not normally audible to the naked ear. Her music explores abstract and recognizable sound worlds and all the spaces in between – which resonated with the artists' own inclination towards the liminal. Mahtani created a rich palette of sonic material inspired by incidental sound recordings made by the artists at Monk's House and their wider material concerns.

In *this voice; this life; this procession*, Woolf's own creative approach and writing strategies – streams of consciousness, atemporality, de-

familiarization – are strategically adopted by the artists in the transmission of fluid and speculative ideas, both on site and in production. In narratological alignment with her 1925 novel Mrs Dalloway, the scanning took place over the course of a single winter's day, revealing extraordinary hues which pulsate with colour as the 'camera' travels above and below the garden, through trees and the writing room. The artists did not foresee how the gradual colouration of daylight into darkness would be captured by the LiDAR and how it would look when processed – the sunken garden became a study in deep chiaroscuro and rich purples, elsewhere the grass appeared unnaturally bright, and the shed itself glowed warmly. Bare trees became white-haloed skeletal structures, ponds were transformed into dark portals and weather-wrapped statues were made sinister through the touch of the laser capture. Achieving this range of colour was largely the result of the natural diurnal cycle with limited daylight. The artists encouraged scanning to continue beyond the usual timeframes deemed acceptable to achieve 'accurate' data, allowing for crepuscular tones in the farther reaches of the garden.

Conversely, Kinect scanning operates best in low light levels, but the captured data is not immediately visible for live reviewing. The Kinect data requires proprietary code in Processing to reveal what has been captured, which offers multiple possibilities for the final visualisation by the artists and their collaborators. The digital incompatibility of the two data sets required an innovative approach to blending the two forms of cloud-data in post-production. Traditionally, one set is designed for domestic motion-capture in gaming, the other for highly detailed, millimetre-accurate architectural site mapping. These differences necessitated an experimental approach to the planning, production and execution of the final work. This misuse of scanning technologies, to explore unchartered and serendipitous outcomes, is an important trope in the exploratory practice of the artists.

The resulting two-channel video projection involved painstaking keyframe mapping to coalesce the fixed data and the live performances in a single cinematic screen. The Kinect performances allow the artists to interpose themselves as impossible sprites; unstable forms composed of shimmering pixels, seemingly moving freely within, yet tenuously moored to, the virtual site. Apparitions rise, fall, dance and spin as dizzying optical illusions are created by the dissonance of the camera's motion, shifts in scale, and the placing of the figures. Jazmine Linklater, writing in *Corridor8*, reflects on this defamiliarizing and disorienting encounter in the gallery:

> The screen is a mass of swarming dots that now gather to resemble the ghost of a sturdy, leafless tree, but now dissolve and coagulate as something else I can't quite name. It is just as Woolf describes the mystery items in her looking glass: "unrecognisable and irrational and entirely out of focus…." (Linklater 2024)

The symbiosis of rendered 3D and 4D data offers the viewer an embodied and temporal entanglement; a cosmology of light and data connected to the nature of all things, as bodies (the artists and the viewers) seem to float, both within the digital space and the immersion of the projected moving image, yet remain intimately connected to the dispersed atoms of branches, trunks, bushes and mosses of the garden. Tuning in to Woolf's sensibilities, Brass Art's attention to the thresholds above and below the data, between visible and invisible, reveals the permeability of all things; a composition of moments; one thing after another. As Woolf writes in *Modern Fiction*:

> The mind receives a myriad impressions – trivial, fantastic, evanescent, or engraved with the sharpness of steel. From all sides they come, an incessant shower of innumerable atoms; and as they fall, as they shape themselves into the life of Monday or Tuesday, the accent falls differently from of old; the moment of importance came not here but there[…]. (Woolf 1925, 189)

Being able to 'move through' the resulting digital data layers that we see in the video, enables us to visualise aspects of the multiple, fragmented versions of reality and time that Woolf herself articulated. John Beagles, in *Sight and Sound* magazine, describes the unsettling impression of geometry and space folding in on itself to create, "a conceptually and aesthetically spellbinding tension between reality and illusion." He observes that:

> The infrared scanning transforms all matter into fragile, spectral veins and atomised pixelated dots of colour. All that is solid really does seem to melt, and like much of Woolf's writing there is that sense of multiple oscillating realities simultaneously coexisting. (Beagles 2024, 87)

In opposition to this atomisation, Mahtani's immersive multi-channel soundscape makes the non-optical, spectral quality of the visuals seemingly more concrete, simultaneously extending the acoustic register of the work vertically in space, and solidifying the relation-

ship between the material, temporal, and cinematic dimensions of the creative space in which Woolf worked.

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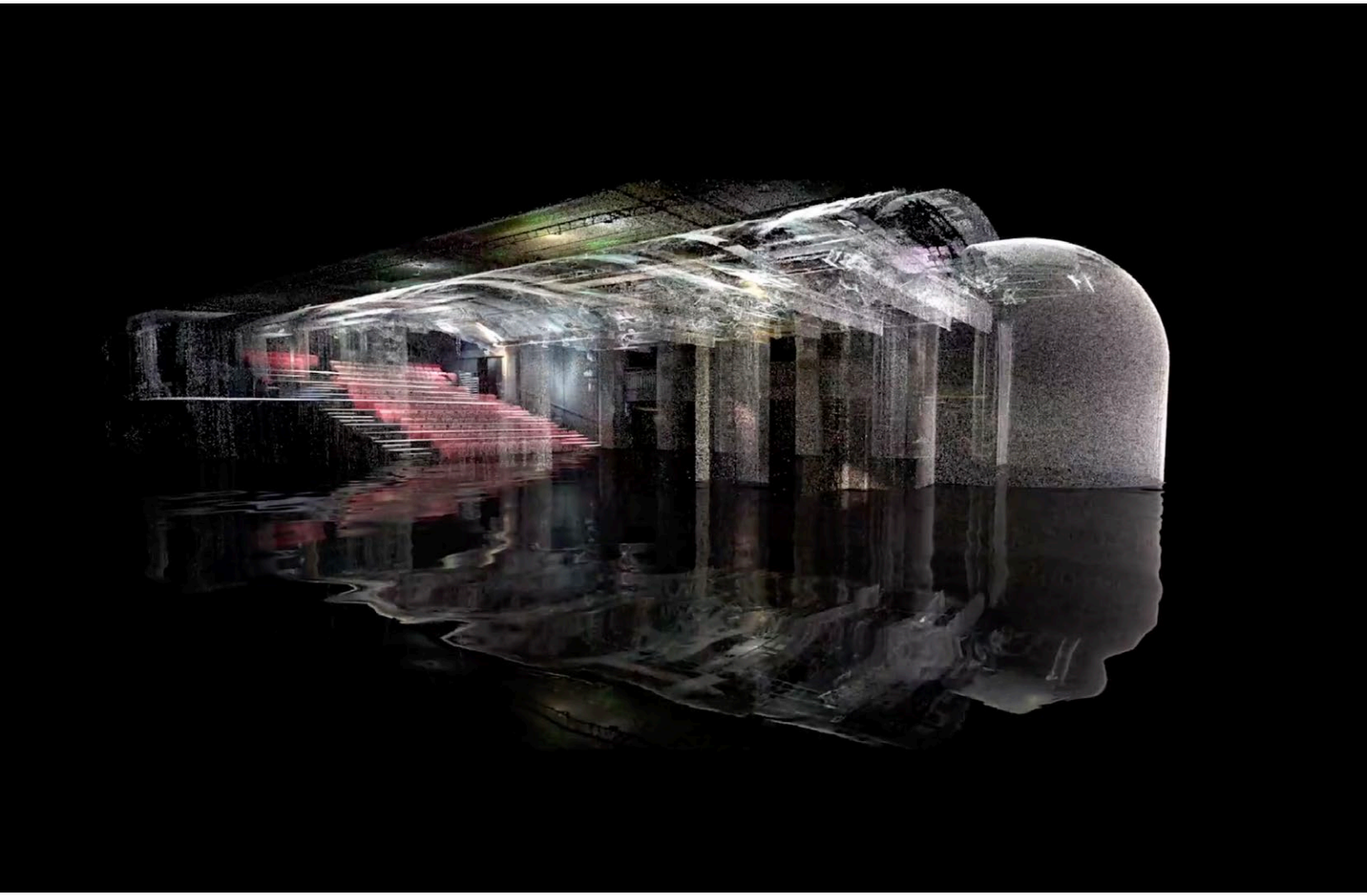
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Oneironautica III: Estrangement

xCoAx 2025
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Dundee, UK
2025.xCoAx.org



Virtual reality (VR) has emerged as a powerful medium for artistic and theatrical experimentation, transforming narrative, space, and perception. *Oneironautica III: Estrangement*, the latest iteration in the *Oneironautica* series, immerses participants in a digitally rendered theatre auditorium using point-cloud aesthetics and volumetric scanning to evoke themes of fragmentation, impermanence, and estrangement. Inspired by lucid dreaming, the experience invites users to explore surreal environments shaped by instability and transformation. At its core, the piece stages four of Franz Kafka's parables as audio-visual sculptures, blending literature, sound, and spatial abstraction. These concise yet dense narratives explore alienation, identity, and the tension between self and others – resonating with the dreamlike and introspective quality of the VR environment. Participants engage as roving spectators, activating and revealing story-worlds through embodied interaction, while the point cloud aesthetic reinforces a sense of vulnerability, ambiguity, and disintegration. This paper outlines the conceptual, aesthetic, and technical foundations of the work.

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Keywords Virtual Reality (VR), Virtual Stage, Immersive Theatre, Point Cloud Visualization, Granular Synthesis, Lucid Dreams

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By situating it within the broader trajectory of VR theatre and analyzing its narrative and interaction design, it highlights how immersive technologies can meaningfully expand theatrical form, spectatorship, and dramaturgical experimentation.

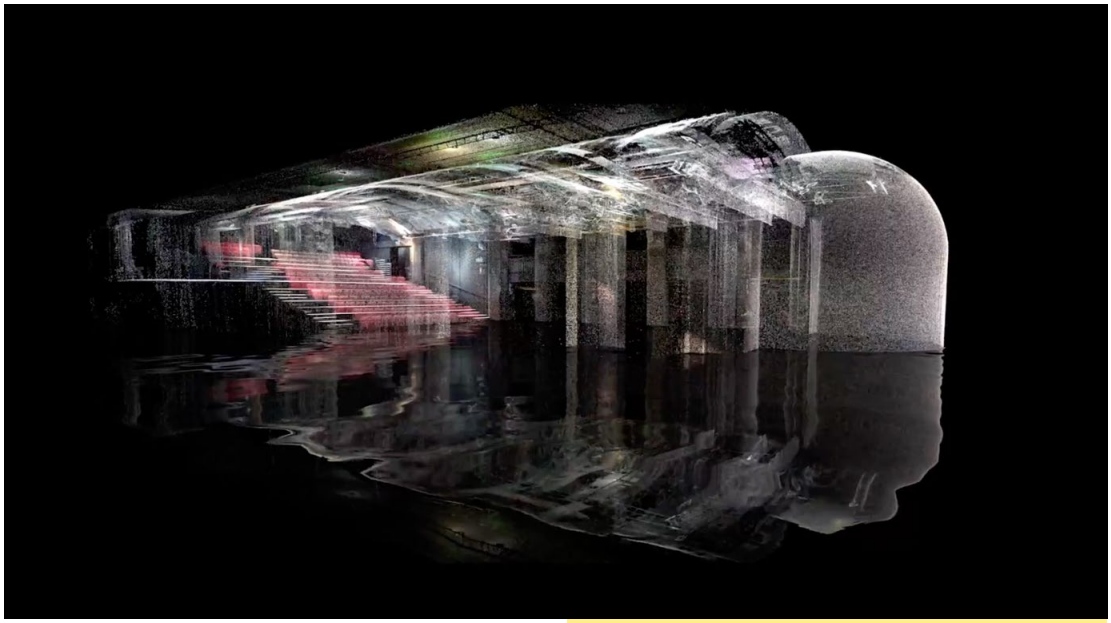


Fig. 1. The first version of *Oneironautica*.

Context and Previous Versions

The interactive VR experience *Oneironautica III: Estrangement* is the latest edition of the *Oneironautica* series, developed by Laurenz Ulrich in collaboration with MIREVI and *Theater an der Ruhr* as part of the project *Theatre of Extended Realities* (2021). In line with the project's goals, this VR piece explores the concept of virtual theatre, pushing the boundaries of storytelling and aesthetic experience beyond traditional stage formats. It engages directly with the growing possibilities offered by new technologies, opening new perspectives on perception, representation, and consciousness.

Theatre is well suited to experiment with new technologies and use them to challenge our understanding of reality and cultural practices. The project addresses several key questions: How can theatre move beyond traditional formats and blur the boundaries between physical and virtual space? How do technologies reshape storytelling and performance? What aesthetic and dramaturgical consequences follow from incorporating digital media? How do such interventions affect the live, collective experience shared by performers and audiences? And how do AI and other technologies reshape our lives and creative practices? These questions are central to the project and informed the conceptualization of *Oneironautica III.*

The initial immersive 3D installation *Oneironautica* was developed by Laurenz Ulrich, a graduate of the Robert Schumann Academy of

Music and Düsseldorf University of Applied Sciences, as part of his Bachelor's thesis. His goal was to contribute to a scholarly understanding of the artistic potential of volumetric recording and point-cloud data (Ulrich 2023). Two artists emerged as key influences due to their pioneering work with point-cloud aesthetics. Ruben Frosali's *Future Cities* presents dreamlike, fragmented urban landscapes (Frosali 2018), while *Dissolving Realities* depicts Vietnamese alleyways that disintegrate upon interaction, evoking impermanence (Frosali 2020). Benjamin Bardou explores perception and memory through digital film and matte painting. Influenced by Walter Benjamin and Baudelaire's reflections on urban life, his *Megapolis* series visualizes cities as dreamlike sequences using point clouds to simulate memory (Bardou 2020). Both artists offered aesthetic and conceptual frameworks that shaped *Oneironautica*, particularly regarding memory, spatial dissolution, and immersive storytelling.

Building on the dreamlike qualities of point clouds, the VR experience *Oneironautica* simulates the audiovisual sensation of waking from a lucid dream. Unlike ordinary dreams, lucid dreams allow a degree of awareness and control, yet remain unpredictable, with shifting environments and fleeting agency (Green and MacCreery 1996). This in-between consciousness inspired the project. VR mirrors this paradox – its immersive quality contrasts with an awareness of artificiality. Rather than seeing this as a limitation, the project embraces it. Interaction design mimics dreamlike exploration, while the unstable point-cloud world reinforces the inevitable dissolution of dreams into wakefulness.

Ulrich chose the *Theater an der Ruhr* as the setting due to theatre´s parallels with dreaming – both are ephemeral, immersive, and blur fiction and reality, reshaping time, space, and identity. The final experience mirrors a lucid dream, with participants navigating a point-cloud theatre, encountering ghostly figures, and hearing echoes of past performances. The environment dynamically responds to their movements before gradually dissolving. This interactive VR installation became the foundation for future iterations in which the virtual stage evolves with new content (Fig. 1). Two subsequent versions have been developed in alignment with thematic focuses of *Theater an der Ruhr*'s season, within the framework of the *Theatre of Extended Realities* project.

The second version, *Oneironautica II*, expanded the installation with a digital dance performance by two avatars choreographed by Charlotte Triebus. Developed with the 2023/2024 season's theme *Rausch* (Intoxication or Ecstasy) in mind, it examined themes of logic,

control, and distorted perception, situating users within a narrative that explored toxic-transformative dependencies. Featuring excerpts from Anselm Neft's play *Vom Licht*, the piece continued the journey through surreal dreamscapes.

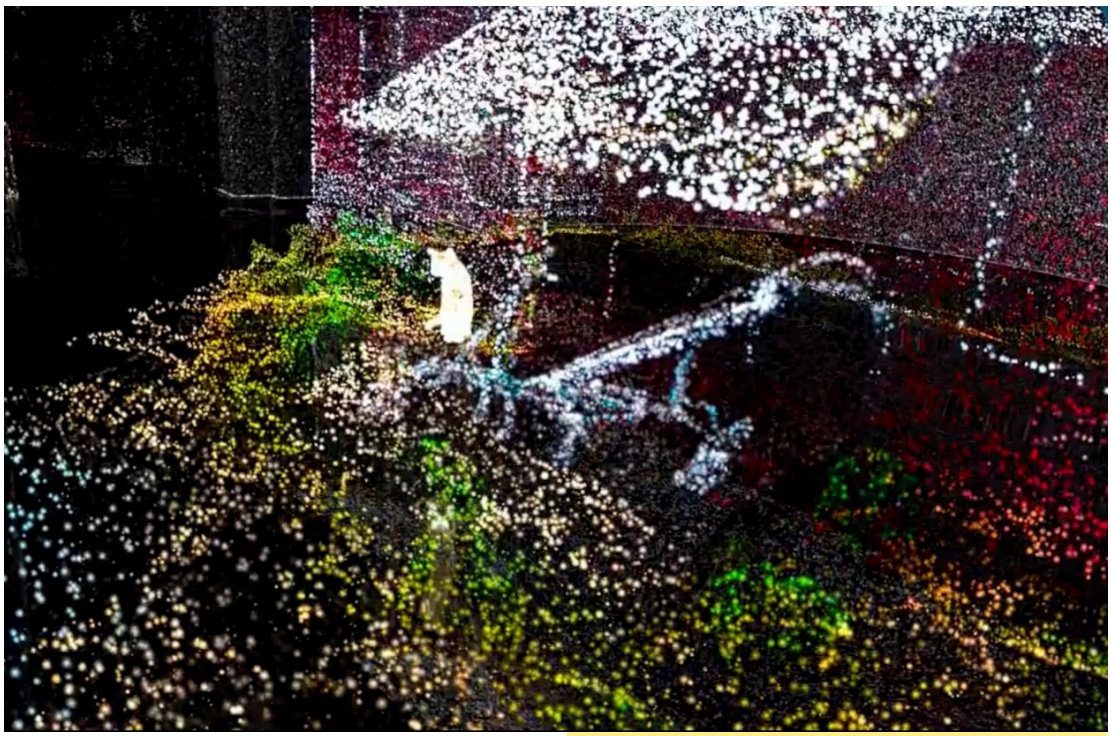


Fig. 2. The house in *Homecoming*.

Description of Oneironautica III

VR Experience

Oneironautica III: Estrangement represents the most complex and thematically rich iteration of the series. Developed within the framework of the 2024/2025 theatre season at *Theater an der Ruhr*, which revolves around the theme *Geheimnis* (*Secret*) – ranging from the intimate to the political – the piece explores notions of concealment, ambiguity, and inner fragmentation through an immersive dreamscape inspired by Franz Kafka's parables. Visitors experience the VR piece wearing a Meta Quest 3 headset while seated on a swivel chair. The experience begins in a vast, dark-blue space, evoking night's stillness and the transition into sleep. A male voice whispers lines from Kafka's short story *At Night*, setting a meditative tone (Kafka 2007). After a while, a bright blue cloud-like portal appears before the viewer. One may choose to wait until the whispered narrative concludes before being drawn into the portal or enter it earlier at will.

Upon entering, the scene transitions to a theatre stage rendered in point cloud aesthetics, gradually assembling before the viewer's eyes. A cacophony of indistinguishable voices fills the space, while four abstract point clouds appear at the edges of the stage, suggesting a presence of figures or objects. As the viewer moves toward

any of these forms using the controller, one of the surrounding voices gradually sharpens into clarity, while the point cloud takes on a recognizable form. Upon reaching it, one of Kafka's parables – Homecoming, The Bridge, The Vulture, or The Fellowship (Kafka, 2007) – is retold by a male or female voice, while the central motif of the story materializes before them. One can choose to stay and listen until the story concludes or continue exploring other areas of the stage. Each representation subtly reinforces the essence of its tale: the house in Homecoming remains inaccessible (Fig. 2), the bridge can be stepped on and crossed, the figures in The Fellowship turn away in indifference (Fig. 3), and the vulture looms ominously overhead (Fig. 4). Regardless of whether all four stories have been experienced, after eight minutes, the theatre scene begins to slowly disintegrate, mirroring the inescapable pull of awakening from a dream (Fig. 5).

As the surroundings completely dissolve, the viewer finds themselves once again in the vast blue void. The same whispering voice returns, this time reciting an excerpt from Kafka's *Letters 1902–1924* (Kafka 1994), serving as a reflective outro.

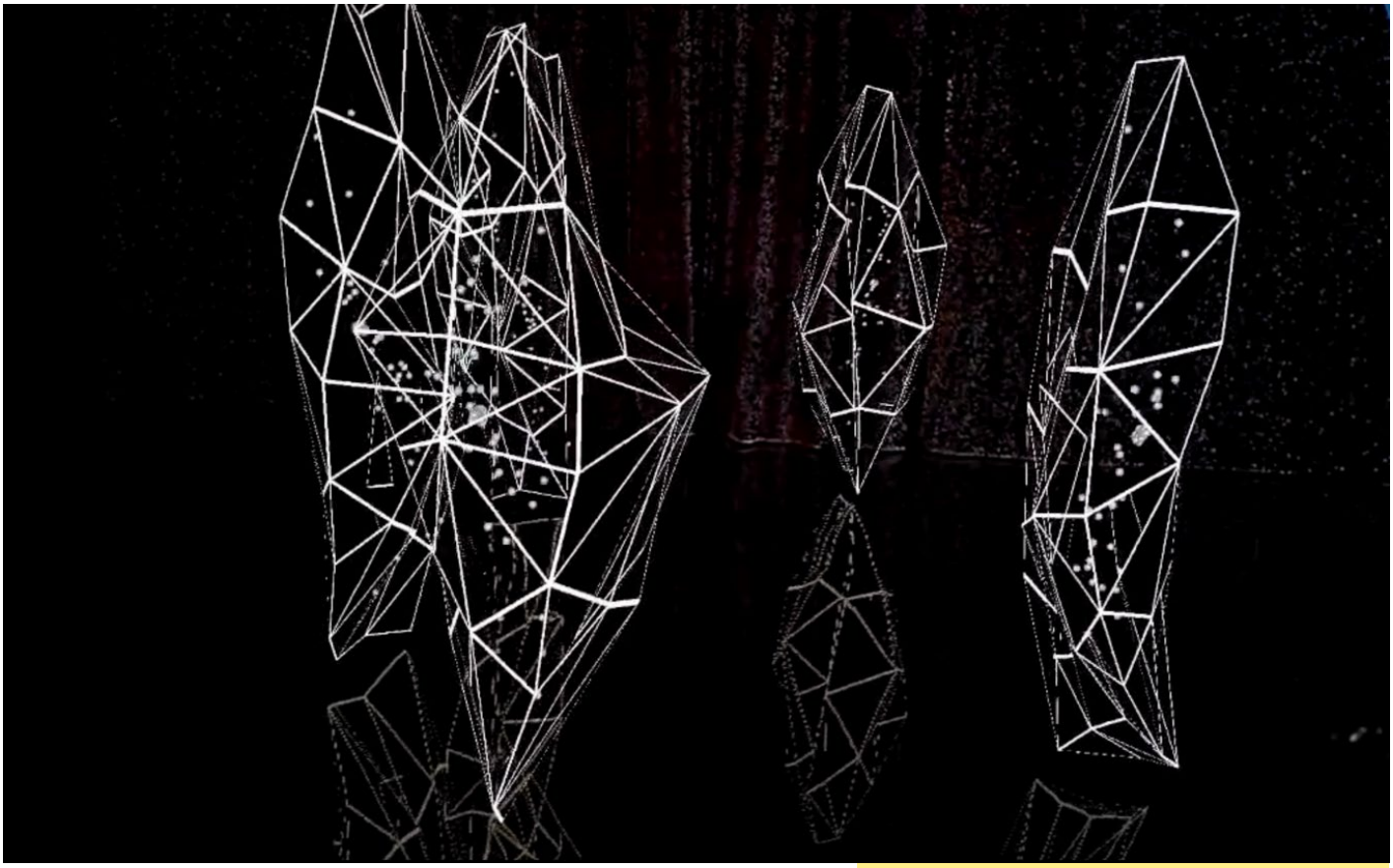


Fig. 3. The figures in *The Fellowship*.

Kafka´s Parables

The selection of Kafka's short stories is both conceptually and personally motivated. Each parable offers a uniquely condensed, symbol-rich exploration of the theme of secrecy, closely aligning with the



Fig. 4. The vulture looms ominously overhead.

2024/2025 season's focus. What unites these narratives is their subtle engagement with forms of concealment – some parables reflect estrangement from the self, some hint at unspoken tensions within close relationships, while others explore the hidden expectations that shape our roles in social settings. In *Homecoming*, the protagonist's sense of alienation hints at an unbridgeable gap between self and origin. *The Bridge* introduces a structural metaphor for fragility and self-sacrifice in the face of invisible burdens. *The Vulture* stages a confrontation with a silent, invasive threat that may reflect suppressed fears or guilt. *The Fellowship* evokes the pain of exclusion from a group whose criteria remain unclear – mirroring social concealment and passive rejection.

As parables, their brevity contrasts with their depth, creating encapsulated worlds that resemble dream fragments – fleeting yet intense, each carrying its own internal logic. Beyond their thematic relevance, Kafka's texts were also chosen due to a personal affinity with his writing – his introspective prose echoed and inspired the conceptualization of *Estrangement* during a particularly resonant time in the author´s life, making the creation of *Estrangement* not just an artistic endeavor, but a personal act of reflection. Within the installation, this convergence of personal resonance, literary depth, and immersive technology invites participants to navigate their own perceptions of secrecy, identity, and connection in a fragmented, dreamlike space.



Fig. 5. The theatre scene begins to disintegrate.

Sound Design

The sound design of *Estrangement* creates an auditory counterpart to the visual experience. The dynamic soundscape responds to the user's position and movement, enhancing immersion. Each Kafka parable is accompanied by a unique soundtrack composed using granular synthesis and spectral freezing. Granular synthesis fragments sound into grains, enabling extreme time-stretching and the indefinite "freezing" of sound, producing an ethereal, suspended atmosphere. By layering these grains – what Hoenig refers to as *grain clouds* – new textures emerge, in which multiple fragments of speech or sound can be perceived simultaneously (Hoenig 2002).

This method mirrors the point cloud aesthetic in both form and perception: discrete elements combine into a coherent but unstable whole. For each parable, three distinct audio tracks were created, varying in recognizability and abstraction. As participants approach the point-cloud sculptures, they activate and shape the audio layers, encountering different levels of intelligibility and sonic distortion. This evolving soundscape reinforces the themes of ambiguity and estrangement, echoing Kafka's emotional and narrative complexity.

The stories are voiced by two German actors – one read as male, the other as female – in both German and English. While this introduces a binary vocal perspective, it also opens space for reflection on identity, voice, and representation – questions the project aims to explore further in future iterations.

Technical Development

The 3D scan was created using a FARO FocusS scanner. 15 scans were conducted across audience and stage areas, each capturing over 170 million points. These were aligned and merged using FARO Scene, then exported in the neutral E57 format. The scans were processed in CloudCompare, where extraneous data outside the theatre space was removed. Further refinements, such as eliminating unwanted stage props, were performed using the Virtual Broom plugin (Ulrich 2023).

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To ensure performance compatibility with the VR environment, the point cloud was reduced to 25 million points – less than 10% of the original dataset – via CloudCompare's subsampling feature and exported in ply format. The final installation was developed in Unity 2021.3.21f1, using the High-Definition Render Pipeline (HDRP) for advanced visual fidelity. Unity's Visual Effect Graph enabled dynamic control of point cloud particles, enhancing the immersive, dreamlike atmosphere (Ulrich 2023).

Presentation

The original installation *Oneironautica* has been presented at several events. *Oneironautica II* was shown at *Theater an der Ruhr* over two seasons in 2024, as well as at tanzhaus nrw in Düsseldorf and the NEXT LEVEL Festival for Games in Dortmund, Germany, both in 2024. The current piece, *Estrangement*, premiered in February 2025 at *Theater an der Ruhr* for the opening of the "Secret II" season. Building on the evolving themes and formats of the series, a fourth version of *Oneironautica* is currently in development.

Conclusion

Oneironautica III: Estrangement reimagines theatrical conventions through immersive technology, translating core elements of theatre – staging, temporality, presence, and voice – into a virtual environment. Though the medium shifts, the work retains a dramaturgical arc, symbolic space, and audience-performer dynamics, positioning VR as a powerful extension of theatrical form.

By dissolving the spatial and temporal limits of the traditional auditorium, the piece invites the audience into a hybrid role – both observer and participant – echoing strategies found in immersive and post-dramatic theatre. The use of point cloud scans of an actual theatre doesn't merely reference a stage; it transforms it into an ephemeral, responsive site of interaction. Narrative unfolds not through linear plot or visible performers, but through spatial navigation, vocal presence, and symbolic *mise-en-scène*. In doing so, the work critiques and expands theatre's conventional infrastructures of presence, embodiment, and spectatorship.

As the series continues to evolve, it opens new pathways for interactive performance and immersive dramaturgy.

Acknowledgements. This work was developed within the framework of the research project *Theatre of Extended Realities*, a collaboration between *Theater an der Ruhr* (Mülheim), MIREVI (Hochschule Düsseldorf), the Academy for Theatre and Digitality (Dortmund), and Dr. Jonathan Harth. It was funded by the Ministry of Culture and Science of the State of North Rhine-Westphalia as part of the NEUE WEGE program, in cooperation with the NRW KULTURsekretariat.

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Being Within

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Being Within explores spatial thresholds as living interfaces by re-imagining architectural structures and enclosures. Drawing from the materiality of natural membranes, the sculpture explores the tension between interior and exterior, liveliness and rigidness. A silicone membrane is animated by a cluster of stepper motors, creating a surface that shifts, expands, and contracts. It is a site-specific sculptural work that reshapes the exhibition room's spatial logic, creating a dialogue between the work and its environment. Visitors are invited to experience the sculpture physically, engaging with it as a presence that is both tangible and impenetrable. The work examines spatial boundaries as porous and invites reflection on the unseen structures that surround us, inspired by the topological concept of interface. Through this interplay, *Being Within* encourages a reconsideration of space as an active, living structure: one that breathes, listens and reacts. *What can permeate through the divide? How is it oozing back what it has soaked in?* Drawing from topological thinking, *Being Within* reclaims architectural limits as a site of differentiation, memory, and response.

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Keywords Membrane, Threshold, Topology, Architecture, Site-specific Sculpture, Interiority and Exteriority, Permeability

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A permeable interface

Being Within is a sculptural and spatial intervention that engages with "limit" as a condition of becoming: it narrates an unseen machinic organism as a point of passage between two dimensions of a building. It is an investigation of spatial ambiguity and material agency that imagines architecture not as rigid enclosure, but a living entity structured by tension, exchange, and permeability.

Leaning into the concept of the "in-between" described by Georges Teyssot in his book *A Topology of Everyday Constellations* (2013), I imagine space not as static, but as continuously composed through relations. By repositioning windows, frames and screens not as simple mediums, but as active thresholds, Teyssot explores the liminality between opposite sets of spaces: visible and invisible, exterior and interior. Similarly, I translate the materiality of skin and plasmatic membranes into an exploration of walls, surfaces, and spatial enclosures as fluid boundaries between two worlds.

In his last chapter, "Windows and Screens", Teyssot presents two relevant references that deeply informed my understanding of space as a symbiotic entity. First, Siegfried Ebeling proposes buildings as living beings, with his text *Space as Membrane* (Teyssot 2013). To Ebeling, space is a medium of exchange and behaves like biological skin: responsive, adaptive and sensorial (Ebeling et al. 2010). With *Being Within*, I am embodying this same idea through a sculpture that mimics membranes in nature: biological structures that separate and connect, simultaneously acting as a division and a permeable interface. This idea that architecture provides both separation and permeability is the main aspect of my sculpture. Secondly, Paul Virilio's *The Lost Dimension* is extremely significant to my research, as he reconsiders the idea of limit with his concept of electronic topology (Teyssot 2013). He defines "limit" as the interface between human and machine: an overexposed and virtualised space restructured by image and code (Virilio 1991). With *Being Within*, I intend to reframe this electronic topology, where instead of a flatness, like Virilio described, the audience can experience an embodied machinic presence.

A sculptural and performative intervention

I make use of silicone to respond to these concepts, creating an architectural presence that is both sculptural and performative. Just as natural membranes define and mediate between environments, *Being Within* enacts a threshold that creates a physical division. The membrane cuts across the exhibition site, separating the audience from the speculative inner consciousness of the building, a living or-

ganism that, although not visible, can be sensed. In this way, the work forces the emergence of an inside and an outside, not as fixed categories, but as spatial roles constituted by the membrane itself. In this redefinition of space, where does the audience lie? Can the exhibition space be now understood as an exterior space, while the real interior of the building stands beyond the membrane? Or is the audience discovering a new exterior beyond the limits of the moving sculpture?

Although the silicone behaves as a boundary, its surface is not a mere separator but a dynamic threshold that responds to and redefines its surroundings. I fiction this presence as a *reaction*: it breathes in the voices, histories and memories of the space, oozing them back with its own independent mechanical patterns. With this, I create the narrative of a networked organism that lives behind the originally impenetrable, but now permeable architecture of each building. What can permeate through these boundaries? What do they absorb and what do they push back to the audience? How do we communicate with them?

Teyssot concluded that life "lives at the limit of itself" (Teyssot 2013, 272), suggesting that life happens exactly at the limit between inside and outside, visible and invisible. My membrane, by being porous and affective, is where difference happens. By making this liveliness apparent locally in each exhibit, I prompt the audience to meditate over the spaces that surround us and the way they are built of exchanges, tensions, gradients, and differentiations.

A tactile exploration

Although not interactive in a computational sense, *Being Within* encourages tactile exploration. The audience is invited to touch the membrane, opening new ways of communication and feeding the membrane with new movements. Below (Figure 1), you can find video documentation on *Being Within*'s exhibition at St. James' Hatcham Church in London. This physical engagement deepens the awareness of the sculpture's materiality, fostering an embodied relationship between the audience and the work: a space for reflecting on the structures we inhabit and how they can communicate with us.

The sculpture consists of a custom silicone membrane (Figure 2) stretched across a frame, actuated by a network of stepper motors (Figure 3) that control its tension and movement. These motors (Figure 4) operate on push and retract commands, allowing for undulating shifts in the membrane's surface (Figure 5). The sculpture also considers sound as a crucial element, as the motors produce subtle mechanical noises due to the friction between the acrylic gears, highlighting the membrane's liveliness.



Fig. 1. Video documentation (vimeo.com/1007644104).



Fig. 2. Making of the silicone membrane.



Fig. 3. Cluster of motors behind the sculpture.

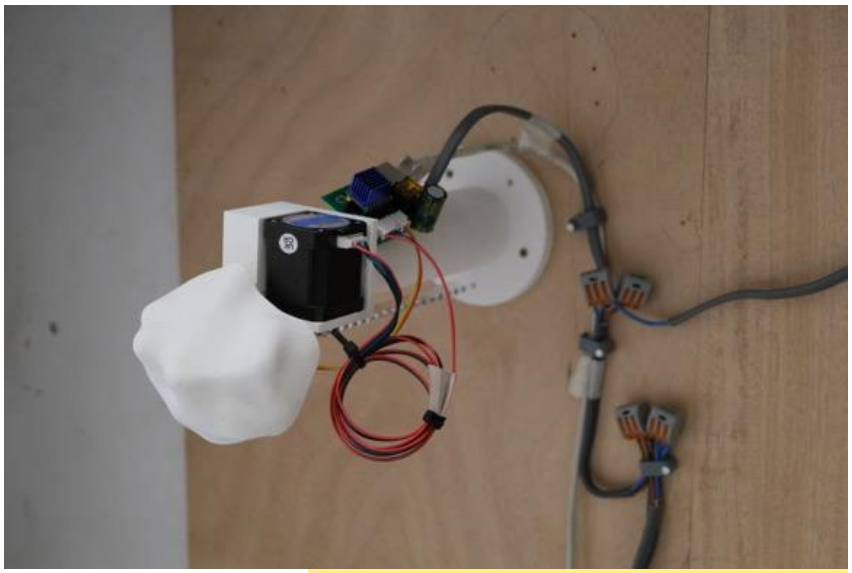


Fig. 4. Close up of one of the motors inside the sculpture.

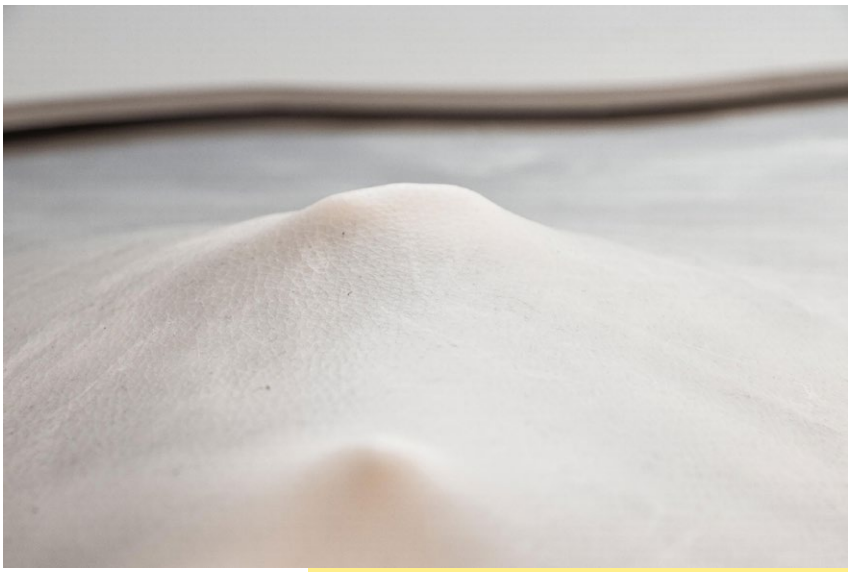


Fig. 5. Close up of the membrane.

Each iteration of *Being Within* is adapted to the specific architecture it inhabits. In past installations, the membrane has occupied recesses and overlooked corners, revealing the unconscious layers of its surrounding space. For the xCoAx conference and exhibition, the sculpture integrates with the space's unique geometries and acoustic conditions, allowing the space itself to shape the membrane's breath.

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Motionforms: A Kinetic Light and Sound Installation

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Motionforms is a kinetic light and audio installation. The installation consists of several identical objects, each comprising a cube-shaped base with four outward-facing loudspeakers and a rotating platform with articulated, illuminated acrylic rods. *Motionforms* exploits motion-induced perceptual illusions to control its visual and musical content. At high rotation speeds, the persistence of vision effect causes the illuminated rods to appear as smooth, radially symmetric surfaces. Simultaneously, the installation emits computer generated sounds whose onset rate is proportional to the rotation speed. At a high onset rate, these sounds form perceivable melodic patterns due to auditory grouping. *Motionforms* is also a generative artwork that operates autonomously. The installation progresses through scenes defined by specific visual and acoustic forms. Scene progression is controlled by a probabilistic finite state machine. This design allows for a predetermined aesthetic progression while maintaining variability and unpredictability in the installation's behaviour.

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Keywords Audiovisual Installation, Perceptual Illusions, Kinetic Art, Light Art, Computer Music, Generative Art, Algorithmic Composition

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Fig. 1. Installation Setup. The graphical rendering depicts four kinetic objects arranged in a line and placed on top of pedestals. Each object rotates and shows a different visual form. The audience observes the installation from a small distance.

Description

Motionforms is a kinetic light and audio installation that demonstrates how perceptual illusions can be exploited for artistic purposes. The installation employs motion to evoke the appearance of visual and musical forms. These forms are the result of perceptual effects that occur when presenting the elementary visual and auditory stimuli at high motion speed. The installation consists of four objects, each equipped with rotating illuminated rods and stationary loudspeakers. Above a certain rotation speed, the persistence of vision effect (Hardy 1920) causes each rod to appear as a smooth surface that possesses radial symmetry. The installation emits a pattern of sounds whose onset rate is related to the rotation speed. Based on the Gestalt laws of grouping (Snyder 2000, 31–46), above a certain rate, the pattern is perceptually subdivided into several auditory streams that appear as independent sub-patterns. During the exhibition, the installation progresses probabilistically through a variety of visual and musical forms, each one characterised by a distinct combination of elementary stimuli and speeds. A possible setup of these objects in an exhibition is depicted figure 1. Several videos are available online that demonstrate the formation of visual and musical forms. Each example video corresponds to one of the configurations depicted in figure 3.

Kinetic Objects

Motionforms consists of several kinetic objects. Each object comprises a base in the form of a cube and a rotating platform (see figure 2). The base houses four loudspeakers, each mounted to one of the four side panels, facing outwards. The rotating platform is embedded into

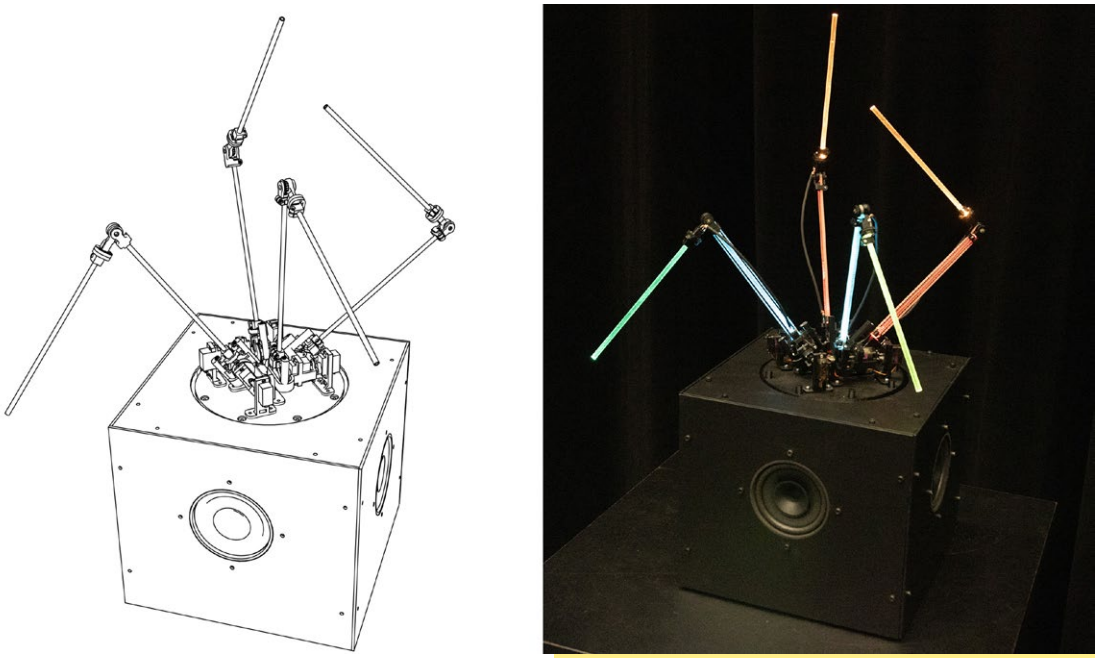


Fig. 2. Kinetic Object. The two images depict a single kinetic object of the *Motionforms* installation. The image on the left represents a schematic drawing of the object. The image on the right is a photo of the built object.

the top panel of the cube. Its rotation is driven by a stepper motor. Attached to the rotating platform are 8 acrylic rods. In pairs, these rods form four articulated arm-like structures that are oriented at 90 degrees from each other. Each arm possesses two revolute joints. A first joint connects the bottom rod to the rotating platform, and a second joint connects the two rods together. Both joints are actuated with servo motors. Attached to the base of each rod is an RGB LED that illuminates the rod. The rotation speed of the stepper motor, orientation of each servo, and the colour and intensity of the light emitted by each LED can be controlled individually.

Light

The colour and intensity of the illumination of the acrylic rods, their orientation, and the speed of their rotation are the main factors that affect the visual appearance of each kinetic object (see figure 3). When the rotating platform is immobile or slowly moving, the acrylic rods appear as lines that are arranged in geometric configurations. Changes in the orientation and illumination of the rods lead to new geometric configurations. If these changes happen gradually and continuously, the configurations appear animated. As the speed of the rotating platform increases, the lines become increasingly blurry. When the rotation speed exceeds the temporal resolution of human visual perception, persistence of vision effects cause the formerly distinct lines to appear as nested rotational surfaces.

Sound

The installation emits a sequence of computer-generated sounds that are organised in a cyclic pattern. There is a twofold relation between these sounds and the visual appearance. First, the properties

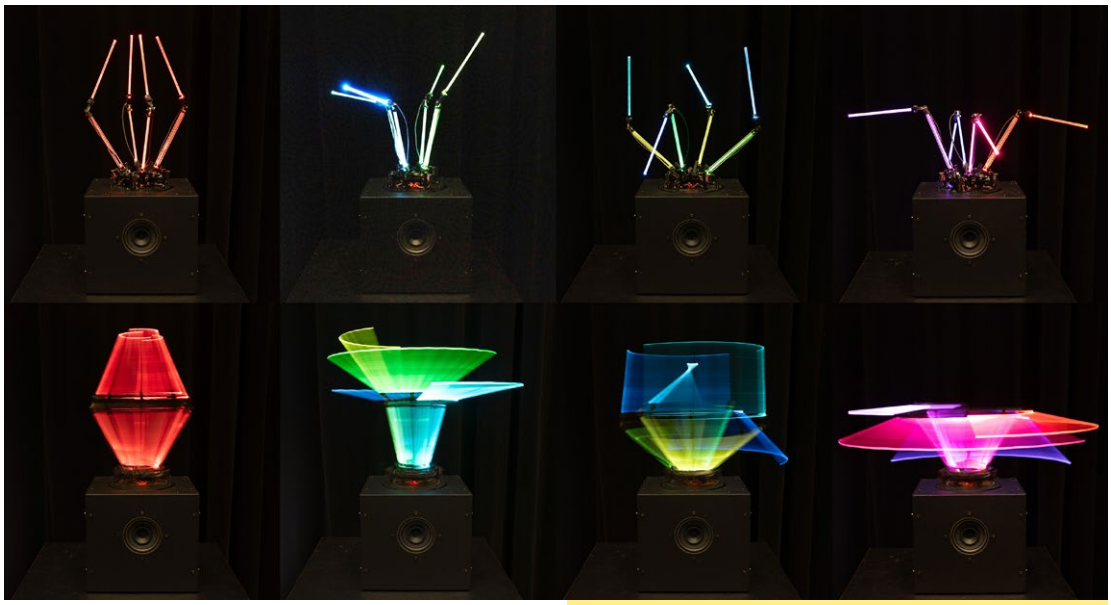


Fig. 3. Visual Forms. The photos show different visual forms that result from different rod configurations. These configurations vary along the rows but are identical in each column. The rotating platform is stationary in the top row and moves at high speed in the bottom row.

of the sounds, such as timbre, duration, and temporal shape, are coupled with the colours and the orientations of the acrylic rods. It is, of course, impossible to define an unambiguous analogy between the visual and the acoustic. However, since every change in one realm is matched by a change in the other, a clearly perceivable connection is created. The second relationship is that the onset rate of the sounds corresponds to the speed of rotation of the platform, which becomes particularly apparent when the speed increases or decreases.

The psychologist Albert Bregman coined the term 'auditory scene analysis' to describe the process by which the human auditory perception organises the received overall sound into meaningful elements (Bregman 1990). "Streaming" denotes the mechanism by which the perception combines sounds that share certain similarities because they originate from the same sources into coherent groups. Two factors facilitate streaming. First, sufficiently large differences between sounds that belong to different groups, and second, a rapid succession of sounds. These differences may concern pitch – most relevant in music – but also any other parameter of the sound, such as timbre, temporal envelope, or loudness. In fact, any systematic perceptual difference can stimulate streaming, provided the onset rate is sufficiently high (Moore and Gockel 2012).

Since the speed of rotation of the platform is related to the playback speed of the sound pattern, several perceptual states are experienced as the speed changes. At a very slow speed, it is almost impossible to detect the overall cyclic pattern, and the successive sounds seem unrelated. At a medium speed, the pattern becomes audible. At a high speed, streaming occurs, and the overall pattern is subdivided into two or more separate streams, each of which is itself a shorter cyclic pattern.

Installation Behaviour

The installation is not interactive and instead operates autonomously by progressing through a sequence of scenes. Each scene is characterised by a particular combination of visual and acoustic forms for all installation objects. The scene progression is based on a probabilistic finite state machine (Vidal et al. 2005) (see figure 4). There exist two types of states: object states and group states. An object state corresponds to the visual and acoustic form of a single kinetic object. This state defines the settings for the illumination and geometric arrangement of the rods, the speed of the rotating platform, and the sound synthesis parameters for sound events. A group state corresponds to a scene which consists of a combination of the visual and acoustic forms of all kinetic objects. Each group state possesses its own internal state machine that controls transitions between object states. A global state machine controls the transition between the group states. For the exhibition, these states and their transition probabilities are designed in a manner that causes the installation to follow a chosen aesthetic progression while maintaining a degree of variability and unpredictability.

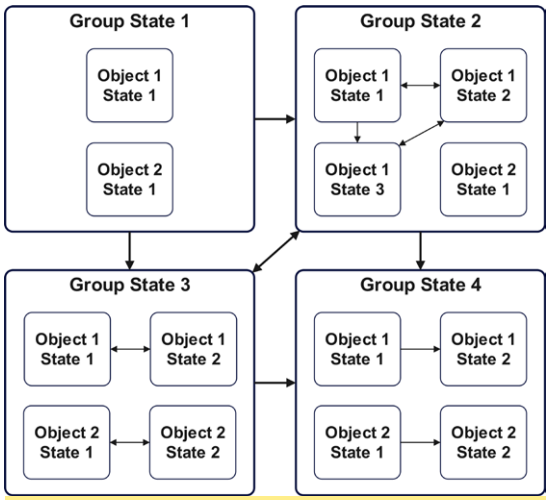


Fig. 4. Installation State Machine. The schematic drawing depicts a possible combination of group states and object states. For simplicity reasons, object states are shown for two kinetic objects only. Boxes represent states and arrows represent possible transitions.

Notes

1. Example Video 1: https://vimeo.com/1056073456.
Example Video 2: https://vimeo.com/1056073567.
Example Video 3: https://vimeo.com/1056073296.
Example Video 4: https://vimeo.com/1056073375.

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Performances

Pulsar Threads

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Pulsar Threads (c.15-18 mins) is an improvised performance versioning of a fixed media release of an existing work, and explores transformation of material sourced from the New Pulsar Generator (nuPG). *Pulsar Threads* explores, often simultaneously, buffer scratching, corpus scrubbing, waveform scuffing, live sampling and a range of time-based, spectral and neural transformations of material. In order to achieve embodied and rapid transitions between different kinds of material, samples from nuPg improvisations have been analysed in a variety of ways using the Fluid Corpus Manipulation (FluCoMa) toolkit to allow for agile polyphonic and gestural exploration and expression using multitouch controllers. *Pulsar Threads* makes connections in material though superimposition, stratification, juxtaposition and interpolation. There's a retroactive injection of the sound and morphology of pulsar synthesis into an established practice of working with sampled material in real-time in ways that are influenced by both early tape works and modern turntablism.

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Keywords Computer Music, Pulsar Synthesis, Sound Corpus, Concatenative Synthesis, Style Transfer, Improvisation, Controllerism

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Overview

Pulsar Threads (Rawlinson 2024) is the latest of a series of works that aim to inject the sound and morphology of pulsar synthesis into my practice while maintaining active continuity with prior work with different kinds and orders of improvising with an established but still evolving "performance ecosystem" (Waters 2007) in ways that are influenced by both early tape works and modern turntablism.



Fig. 1. Multitouch Controller Setup.

Specifically, *Pulsar Threads* explores, often simultaneously, buffer scratching, corpus scrubbing, waveform scuffing, live sampling and a range of time-based, spectral and neural transformations of material sourced from the New Pulsar Generator (nuPg) . To borrow a phrase from Bolt's work on practice-led research, if there is any magic to be found here, "the magic is in the handling" (Bolt 2007) and concerned with material thinking. This music is characterised by fast moving detail, development and interactions between sound objects and embodied technique to make connections in material through superimposition, stratification, juxtaposition and interpolation.

Pulsar synthesis is capable of a wide range of expressive and engaging timbres and forms, but I just can't play nuPg fast enough, or really, I can't play it fast enough with the required precision and agility for creating responsive real-time onset, continuation and closure of sound events at multiple time-scales that cluster and collide then fragment and dissipate, with varied and morphing envelopes, arcs and sharp changes in direction.

nuPg's screen-based interface is more supportive of longer timescale and pre-planned forms when used in live performance. In order to achieve more embodied and rapid transitions between different kinds of material, samples from nuPg improvisations have been analysed in a variety of ways using the Fluid Corpus Manipulation (FluCoMa) toolkit to allow for agile polyphonic and gestural exploration and expression using multitouch controllers that offer differing kinds of continuous, rather than discrete or quantised, control.

Keep's concept of "instrumentalizing" is the discovery of the inherent character and opportunities for manipulation of sound in sounding objects (Keep 2008), and since 2007 I've been working towards instrumentalising high resolution multidimensional surfaces in combination with MaxMSP software and digital sound files in order to achieve rapid gestural and textural transformations of pre-recorded sound files of varied character and differing durations, from milliseconds to minutes. Beginning with a graphics tablet and what has been described as "mixed sensing" I've explored a range of typical tablet gestures (Zbyszynski M. et al. 2007) which, together with scrubbing

and scratching, include dipping and bowing across different kinds of sampling and synthesis methods and material. Additional interfaces augmenting the system include a DJ-Tech USB turntable, Keith McMillen Instruments Quneo offering pressure and location sensitive pads, and a Faderfox compact midi controller.

With time the graphics tablet has given way to a Sensel Morph multitouch device offering greater opportunity to explore simultaneous contrasts and traversal of timbre and temporalities in material. Different approaches to creating and manipulating sound include sample segment triggering and micro-looping, spectral resynthesis, granulation and more. The system uses a range of mapping strategies and design in the interaction of the different DSP layers such as non-linear controller values, and (un)control and unpredictability in the live sampling processes as my attention and intention shifts between simultaneously sounding layers of points, lines and planes in motion.

As the system has developed for different use cases or works, it's generally followed Cook's principle of "Instant music, subtlety later" (Cook 2001). There's an immediacy to triggering sounds, but also a complexity to shaping them, even before we begin to process them. The performance system here meets a number of Croft's conditions for instrumentality (Croft 2007). The scale of physical gestures on the multitouch surface affects the scale of audio output in a fine-grained way, the responses of the software outputs are tightly synchronous with my gestures and generally my dsp processes follow or match the energy motion trajectories of the input audio. The relationship between my actions and the computer is (mostly) stable, and for people watching a performance, there's a visible relationship between action, effort and sound, a "performance ecology" (Bowers 2002).

One aspect of the setup that's easily ignored is the ergonomic assemblage of the system, allowing for single handed control of more than one device simultaneously through consideration of placement and impact on gesture. The surfaces themselves have a series of constraints, e.g. how many fingers can I place on a device before I get in my own way due to size of my fingers and surface, how far can I stretch my fingers, how can I place pressure on one finger and not another, while stretching? In some ways these concerns are not unlike those of player of a stringed instrument such as a violin, especially while double stopping, playing more than one note at once, and perhaps sliding between notes. Some of this control then might be "ergomimetic" (Magnusson 2019), an imitation, translation and transformation of gestures and practices from one instrument or interface to another.

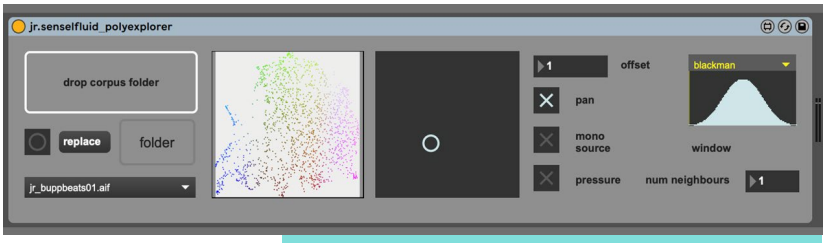


Fig. 2. Custom FluCoMa analysis and clustering Max for Live instrument.

I've designed in "explorability and learnability" (Orio, N., Schnell, N. and Wanderley, M. 2001), and occasionally 'bug' becomes 'feature'. One example of this is polyphonic voice stealing. Reflecting on some glitching that was the result of too many simultaneous multitouch points and too few available voices I thought, "Oh, OK, increase the voice count", then, after a reflective pause, "Oh, no, leave it, because it gives me another place (distortion, saturation, and stuttering overload) to go". This is playful, what Green might describe as a decision to not use tools 'properly' (Green 2011), but also results in opportunities to create emotionally and expressively charged "highly aestheticised digital bits" (Rogers 2003).

This work also explores processing of sound in ways that my previous work with nuPg such as *Pulsar Retcon* (Rawlinson, 2021) has not. In part, this is a result of working more deeply and regularly with nuPg itself, spending more and better time with it. Having moved from initial exploratory sessions to arrive at informed improvisations with shaped sound output, there's more causal understanding and detailed control of nuPg, leading to a more varied palette of pre-recorded material for further typological and transformational discourse and development of sonic morphology (Smalley 1994).

There's also more extensive experience of improvising with the already improvised outputs from nuPg, in mapping them to surfaces and software processes, in understanding the possibilities for threads of connection and combination in and of material. These performed sounds are then sent to multiple auxiliary destinations for further temporal and spectral processes of stuttering, scanning, freezing and looping, of which, these processes can also send to each other in an extended feedback network.

Beyond the auxiliary processing, there's a final couple of developments explored here that aren't present in my earlier solo work in any form. The first is the use of the Fluid Corpus Manipulation (FluCoMa) toolkit for corpus-based similarity analysis, dimension reduction and clustering of fragments of sound across a series of newly developed multitouch controlled software instruments, creating an interpolation space for highly expressive sounding action.

The same kinds of corpus analysis can be used for live input audio matching, where sound input triggers further sound output that is related to the original material across different descriptors. In addition, this work employs neural style transfer, where sound is resynthesised using the timbral characteristics of a trained model. In this case the model has been trained on an improvisation by saxophonist Franziska Schroeder , and my patch allows control of four out of sixteen latent vectors so that I can direct the output character in real-time while keeping sound output roughly proportionate to the energetic characteristics of the input audio.

Overall, there's a rich set of possibilities for monophony and polyphony, precision and instability, simplicity and complexity leading to a wide range of possible outcomes.

Notes

1. https://github.com/marcinpiet/nuPG_1.0

2. https://www.flucoma.org/

3. https://huggingface.co/Intelligent-Instruments-Lab/rave-models

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AETHRAKHTHON: Structuring Electroacoustic Improvisation and Performance Using a Game Engine

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AETHRAKHTHON is a game-piece utilizing an electronically augmented drum-kit as an interface with a physics-driven game environment. The work explores improvised musical structures where the physical dynamics of the game world influence live sound processing and electronics. Through the interplay between the drum-kit and the game engine's physics, the performer navigates a space of sonic possibilities, generating a dialogue of audiovisual interactions. This open-ended structure encourages exploration, allowing for unique interpretations in every performance. The result is a dynamic and evolving experience where the boundaries between sound, motion, and technology blur.

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Keywords Improvisation, Performance, Game Design, Live Electronics, NIME, Electroacoustic Composition

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AETHRAKHTHON

AETHRAKHTHON is a piece for the augmented drum-kit, a hybrid instrument that bridges the acoustic and digital realms. The drum-kit consists of a traditional setup enhanced with sensors, contact microphones, and speakers, all integrated with bespoke software. This configuration transforms the drum-kit into a dynamic control interface for live electronics, game engine, and visuals. Using machine listening techniques and gestural analysis, the performer's physical actions directly shape the sound world and game environment, creating a highly immersive and physical performance. The interaction model minimizes reliance on conventional controller interfaces, with the laptop functioning solely as a mediator for the diverse system components. All controls for electronic sound, lighting, and projection are handled through the acoustic drum-kit, allowing the performer to focus entirely on their instrument. This approach emphasizes a seamless integration of the acoustic and digital, resulting in a performance system that feels both organic and intuitive.

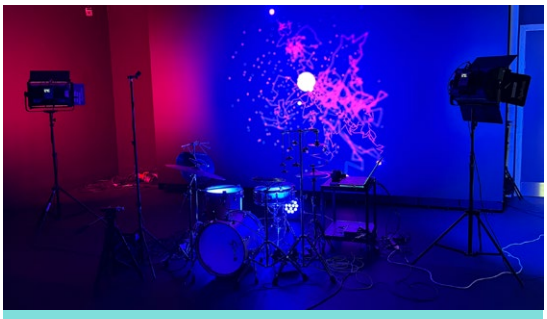


Fig. 1. *AETHRAKHTHON* setup.

The piece makes use Unity's physics engine, utilizing the physical gestures performed on the drum-kit to generate sonic and visual representations. Through sample-based and synthesis techniques, as well as real-time audio processing, these gestures are mapped to actions within the digital game space. This extension of the drum-kit into the virtual environment enables a dynamic interplay between physical and digital worlds, where the performer's actions trigger both auditory and visual actions. The sound palette created by this augmented drum-kit has been documented in several solo releases, including *Frrriction* (2012) and *Long Distance* (2013).

Game Design and Interaction

The performer navigates through different game scenes, each offering unique mappings of physical gestures to sonic and visual outcomes. The environment serves as a space for experimentation, where the performer interacts with and responds to the system in real time, discovering the relationships between physical actions, sound, and visuals. These are projected onto a screen behind the performer, with the audience sharing the same feedback experience. This creates an immersive performance setting, drawing viewers into the dynamic interplay between sound and movement. Interaction within the environment ranges from clear and immediate cause-and-effect relationships — where a drum hit directly influences the visuals or sound processing — to more nuanced and abstract mappings. These variations challenge the performer to continually adapt and respond, creating

a performance that balances control with discovery. Musically, the digital environment acts as a type of graphic score. While it provides a structured framework for the performance, it also leaves room for interpretation and improvisation. The relationship between the performer's gestures and the system's responses generates a unique performance each time.

The piece is designed as a solo performance lasting between 10 and 60 minutes, with duration determined by the performer's artistic intentions and the flow of the game.

Previous Work

This work builds upon previous pieces using game engines as tools for musical performance. Previous works include both solo and ensemble pieces that leverage game mechanics and environments to shape sound and interaction. These projects range from experimental games controlled by conventional game controllers to instrument-specific games designed for acoustic instruments. Notable among these works is *Pathfinder* (2016), a game-piece premiered at ICLI 2016 and subsequently performed at various festivals and conferences such as NIME 2016, DiGRA 2016, Sonorities 2016, and ICMC 2017.

Documentation:
https://www.youtube.com/watch?v=XW4NCk6GXj8

Website:
https://christosmichalakos.com/

Modulating Time

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Live coding performances typically rely on machine-driven time synchrony. While this removes the challenge of manual synchronisation, it also abstracts away the embodied experience of rhythmic entrainment – a core aspect of musical improvisation. This performance explores an alternative approach to time modulation in live coding by replacing machine synchrony with physical interfaces. Through this, we investigate the expressive potential of drifting in and out of synchrony, phasing effects, and rhythmic transformations inspired by Carnatic geometric rhythms and tala structures.

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Keywords Live Coding, Improvisation, Embodied Performance, Physical Interfaces, Experimental Music

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Motivation

> Sound [...] appears as a symptom of time. In the ambiguity between active and passive aspects of timing, it functions somewhere halfway between actively drawing together and identifying disconnected moments and passively signalling their coincidence. (Rohrhuber 2018, 19)



Fig. 1. Wilson (left) and McLean (right) at performing at PIF_Camp.

Live coding performances – where a live coder will write code in an improvised way to create various art forms (Collins et al. 2003) – are often driven by some kind of clock. Where two people collaborate, time synchrony needs to be achieved between them, and this is seen as a software problem, to set up oscillations across network cables to bring two computers into synchrony. Several live coding systems have standardised on the free/open source *Link* protocol and library created by Ableton, allowing time synchrony across these systems, locked in phase to a tempo.

This works so well, that it is hard to see the trade-offs of this approach. There is no need to manually beat-match, or think about synchrony at all – any one of the performers has full control over each other's tempo, any change made is made perfectly together. Prior to time synchronisation standards, live coders would have to agree on a tempo, start their clocks at the same time, and stick to the same tempo while hoping their clocks don't drift out of sync. Clearly, the shared Link clock is an improvement on this situation.

However, the problem is that rhythmic entrainment, the time synchronisation between musicians, is normally a central part of music making, which Link is abstracting away. Although the use of click tracks has become common, there is still something special about how a group of improvising musicians fluidly negotiate time as an intrinsic part of the musical outcome. Live coding culture has gone from the frustration of having little or no possibility to synchronise time, to having the issue completely 'solved' in software and hardware, but where the rich possibilities of human entrainment in code-based performance is lost. Furthermore, when a live coder wishes to collaborate with instrumental performers, the reliance on computer-based clocks has meant that live coders have tended to monopolise control over time, in that the instrumental performer can only follow the live coder's clock. We see this as a symptom of a general distance between humans and time in live code performance, despite live coders otherwise celebrating being embedded in time.

Prior work

While resident at the week-long “PIFCamp” art camp (PIF_Camp 2024), we collaborated with textile artist and technologist Mika Satomi, exploring possibilities for modulating time with physical interfaces. This followed our earlier collaborative work exploring the integration of e-textile sensors with live coding (Wilson et. al, 2023). We worked on handheld stick-based and woven devices for tactile control of musical pattern and tempo. We then used these devices to manipulate time in our live code duo, eventually passing them into the audience for people to dance with. On a technical level this was achieved with an IMU on a wireless microcontroller integrated into woven grasses, using autocorrelation to identify tempo (Lartillot and Grandjean 2019).[1]

The artists’ experience through performance began to challenge how audience-controlled synchronicity might work in practice. Through vigorous end-of-camp dancing, the sticks experienced natural wear, briefly challenging our control over time. This unpredictability, while disorienting, became an integral part of the experiment – revealing new possibilities for temporal engagement.

This experience inspired the next iteration that we will present at xCoAx.

Prior to this collaboration, McLean and Wilson have also performed live coding both separately and together, around the UK and internationally, under the pseudonyms ‘yaxu’ and ‘digital selves’ respectively.

Proposal

This performance will focus on live coded, from-scratch improvisation between ourselves, without machine synchrony. Instead, we will explore synchronisation through physical devices, as an iteration of our collaboration with Mika Satomi. Through this we will open up exploration of smooth tempo changes where we purposefully drift in and out of synchrony to create phasing both in terms of long-form musical changes, and microtemporal comb filtering. We will also explore geometrical rhythmic transformations inspired by carnatic rhythms (McLean, 2024), to push the possibilities of polymeter in fluid time. Here one will focus on tala-inspired short form repetitions, providing the ground for the other to explore longer form expansions and reductions. We will resolve and conclude these experiments by briefly switching to a machine clock, to create tangible rhythmic counterpoint, before ending the performance in complete temporal disarray.

Acknowledgments. Alex McLean's contribution is supported by UKRI Future Leaders Fellowship Algorithmic Pattern, ref <MR/V025260/1>.

Notes

1. For details, please see the prototype-quality source code uploaded here: https://github.com/Patterns-in-between/aacp/blob/main/py/tempo/tempo-minimal-imu-madgwick.py, as well as the video documentation from PIFCamp:

https://youtu.be/MJL0rzY-iWA?si=AL3eYZTHprHXtyJ0&t=71.

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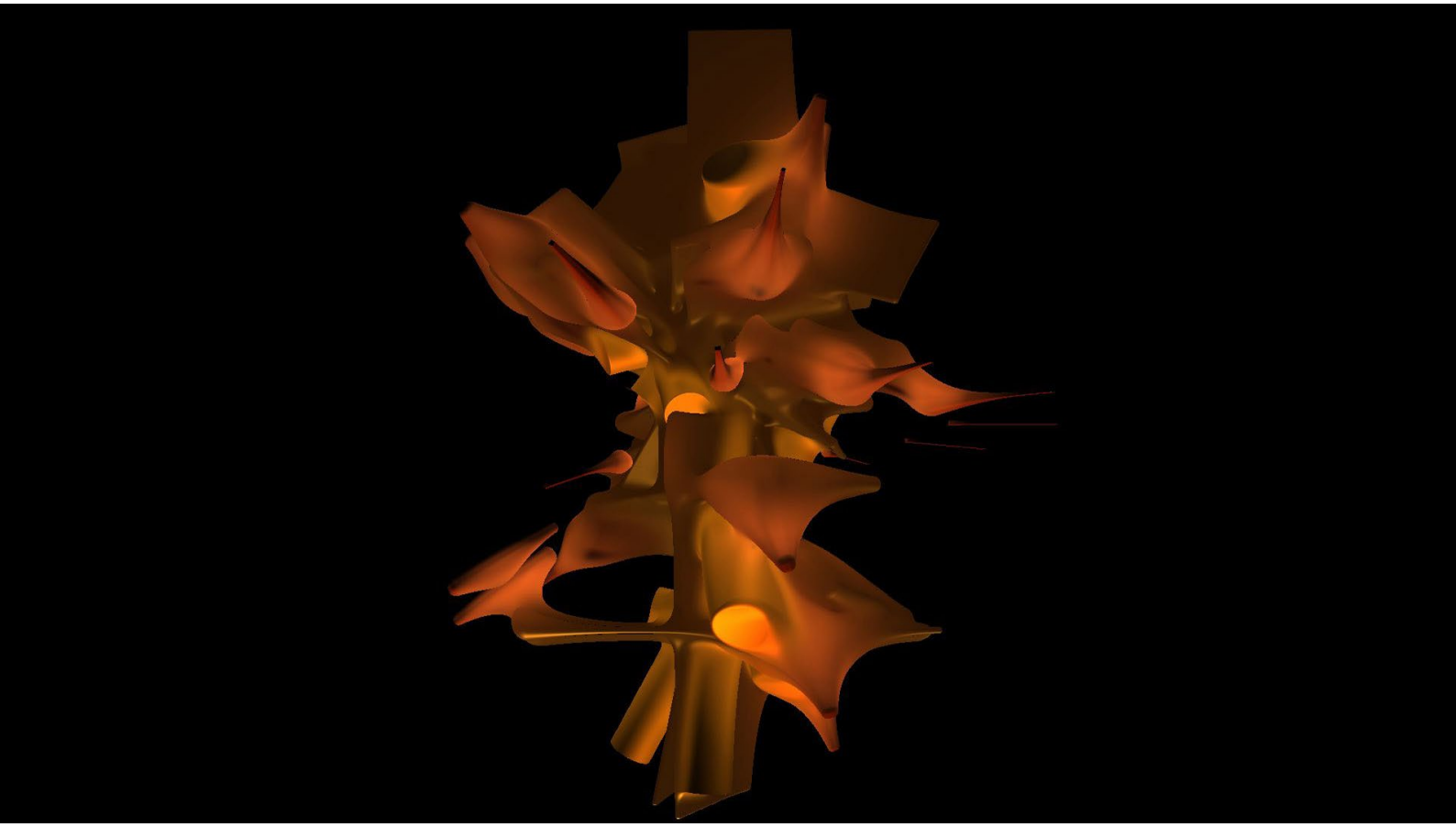
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Sonosphere: A Spatial Music Instrument for Human and Artificial Dancers

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Sonosphere is an artistic tool that functions as a digital instrument, audiovisual installation, and creative platform for realizing and showing new performance works. These performance works bring together contemporary dance, electronic music, computer-generated visuals, and generative AI. As a digital instrument, *Sonosphere* responds to bodily movements, triggering spatially distributed sounds. As an audiovisual installation, *Sonosphere* creates both music and computer-generated visuals that can be interacted with by a visitor or a generative AI, either of which takes over the role of a dancer. As a creative platform, *Sonosphere* offers musicians, media artists, dancers, composers, and choreographers a collaborative space to realize and demonstrate new works. Over the past two years, students and lecturers from the media faculty at Hochschule Offenburg have partnered with a professional dancer to create several pieces for *Sonosphere*. A selection of these works is showcased at xCoAx 2025 in a concert performance.

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Keywords Digital Instrument, Audiovisual Installation, Creative Platform, Generative Artificial Intelligence, Contemporary Dance, Computer Music, Motion Capture, University Teaching

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Fig. 1. Dance Improvisation with Digital Instrument and Motion Capture. The photo shows a moment during the creation of artistic content for the *Sonosphere*. Several students are observing how the dancer improvises with their audio material while being recorded by a motion capture system.

Introduction

Sonosphere is an audiovisual installation and platform for performance works that combine contemporary dance, electronic music, computer-generated visuals, and generative AI. Simultaneously, *Sonosphere* functions as a digital musical instrument played through dance movements in space. These movements can be generated either by a human dancer or by a generative AI trained on previously recorded dance movements. The mediator between the instrument and the dancing entity is an avatar that is surrounded by a virtual sphere. Sound-generating points are placed on the surface of this sphere. The avatar executes the movements performed by the dancing entity. When these movements bring the avatar's extremities close to the sphere's surface, the sound points located there are activated. The combination of avatar and sound points is made both audible and visible. The activated sound points emit sounds that are generated from recorded audio material. The avatar and sound points are graphically rendered as a unified abstract visual entity.

Over the past two years, students and lecturers at Offenburg University have experimented with this setting in collaboration with a dancer and created several artistic works for the *Sonosphere*. These works are publicly shown for the first time at this year's xCoAx conference in the format of a concert performance. During the concert, the works are remixed in a live improvisation. The improvisation involves the manipulation of the movement-generating AI and the control of parameters for sound generation and graphical rendering.

Concept

Sonosphere establishes an interface between human and machine through which digital representations of musical, visual, and choreographic material can be recombined and made accessible for performative manipulation and reinterpretation. Through the use of a generative AI that creates artificial dance movements, *Sonosphere* can operate with some level of autonomy. As a result, interaction with *Sonosphere* resembles a dialogue-like collaboration. The instrument assumes the role of a partner who shares some authorship with its human counterparts.

One main focus of the work is establishing a creative space where the relationships between the actors and their numerous possibilities for agency manifest in diverse ways. The actors include the choreographer and dancer, who seeks a performative approach to play the digital instrument while simultaneously creating the movement repertoire available to the AI. They include composers, musicians and media artists who define the sonic and visual material and alter the original choreography by manipulating the AI. They also include the installation visitors, who can choose their own roles as passive observers or active participants. Finally, they include the AI which oscillates as a partially autonomous entity between cooperation and recalcitrance towards its human partners.

A second main focus of the work is the adoption of Laban's concept of the *Kinesphere* (Brooks 1993) within the installation. *Sonosphere* establishes a direct link between digital instrumentation and the choreographic principles of spatially expansive dance. In this work, virtual sound points are arranged on the surface of a sphere, with the dancer positioned at its centre. As the dancer traces movement pathways – referred to as "trace forms" by Rudolf Laban – their limbs interact with specific sound points, triggering the playback of corresponding sounds. This interplay fuses physical and musical expressiveness, enriching the dancer's choreography through both movement and sound.

Sound Generation

The sounds are generated using a digital instrument that can be played by the dancing avatar. The instrument consists of multiple sound points distributed on the surface of a virtual sphere (see figure 2). Each sound point is associated with an audio file. The dancing avatar is located at the centre of this sphere and triggers the playback of an audio file by approaching the corresponding sound point with one of its extremities. The number of sound points and

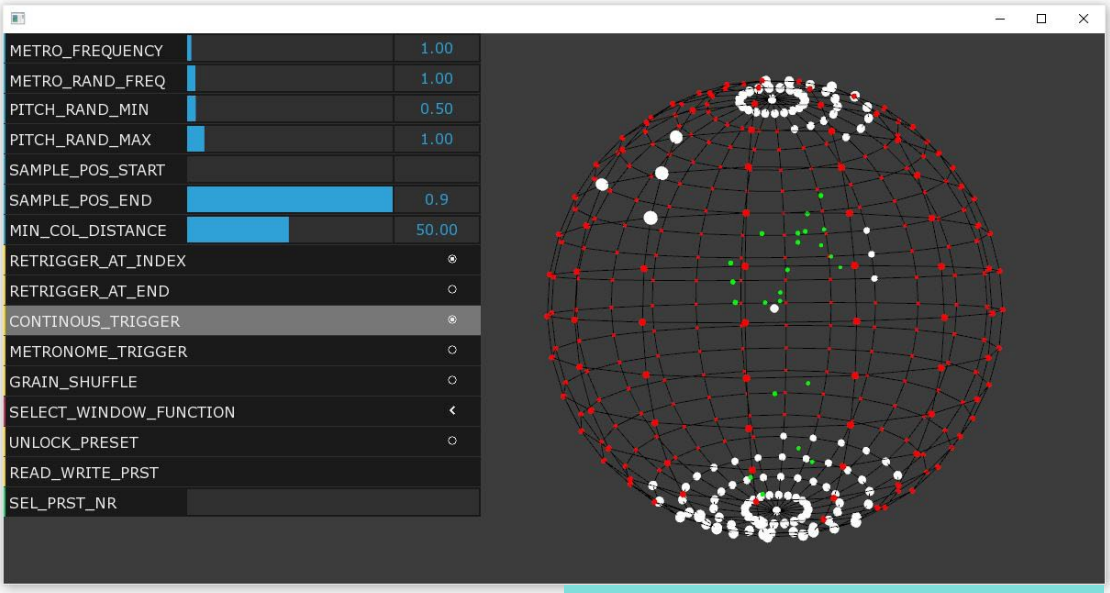


Fig. 2. Screenshot of the digital instrument. The sound points and the dancing avatar are represented as simple 3D visualisation on the right side. In this visualisation, small green dots represent the joints of the dancing avatar, small red dots represent inactive sound points, and large white dots represent sound points that are currently played. The graphical user interface for configuring the parameters for audio playback is shown on the left.

the selection and assignment of audio files to these points significantly influence the performative possibilities of playing the instrument. In some works that have been realized so far, the assignment was executed automatically by sorting the audio files according to chosen audio descriptors. In other works, the assignment was conducted manually. Various options are available for playing the audio files. The audio files can be triggered when falling below or exceeding the minimum distance between the sound node and the dancer. Triggering can occur once or repeatedly, after or before the respective file has stopped playing. The audio files can be played in their full length, as small excerpts, or recombined using *Granular Synthesis* (Roads 1988). The playback speed can be randomly varied between lower and upper boundaries.

Motion Generation

The motions performed by the dancing avatar are either captured live from a human dancer or generated synthetically. In the latter case, a generative AI trained on movement material is employed. This movement material originates from improvisations by dancer Marcella Centenero, which she developed and used for interaction with the digital instrument. These improvisations were captured using a professional motion capture system[1] and used to create a training dataset.

The generative AI employs a neural network model consisting of classical LSTM units (Hochreiter and Schmidhuber 1997). This model is trained using an autoregressive procedure and employs a curriculum learning strategy (Wang, Chen and Zhu 2021). The generative AI learns to predict future dance motions based on a given start motion sequence. These predicted motions represent variations of the original dance improvisation while preserving the improvisation's

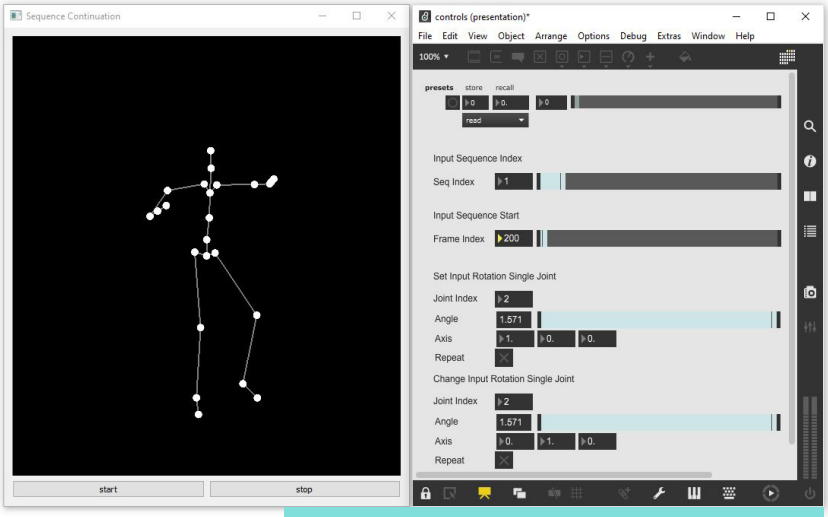


Fig. 3. Screenshot of the generative AI software. The generative AI produces the motion of a dancing figure represented as a stick figure (left side). A graphical user interface allows one to intervene with the motion generation process (right side).

movement repertoire and stylistic characteristics. At the same time, the predicted motions gradually deviate from the original improvisation over a long duration. The deviations manifest themselves as alterations in the temporal sequence of movement motifs, new combinations from different improvisations, a predominance of repetitive elements, and an occasional stagnation. Thus, the AI's motion generation occupies a middle ground between authentically reproducing the original improvisations and autonomously creating new dance motions. The AI operates in real-time, and its motion generation can be interactively influenced. Currently, there are two options for interaction: 1) Selecting a new start motion sequence to be continued by the model, and 2) Overwriting individual joint orientations in the motion sequence used as input by the model. The first option leads to significant changes in the motions generated by the model, while the second option only minimally alters the generated motions.

Image Generation

The avatar and the sound points are made visible as a unified abstract entity by using the Ray marching rendering technique (Tomczak 2012). *Ray marching* is based on the principle of a ray that scans a virtual space for collisions with geometric primitives. The ray is emitted for each pixel of the image to be produced. The geometric primitives are mathematically described as functions that calculate the distance between a point in space and the primitive's surface. The method is computationally demanding, but offers the possibility that primitives can be easily deformed and merged into intricate and seamless surfaces. This possibility can be exploited to vary the appearance of the dancing figure and the sound points and to merge them into a singular visual entity. The appearance can continuously vary between humanoid, amorphous, and platonic forms. The generated image thus conveys the status of the artificial dancer as an entity

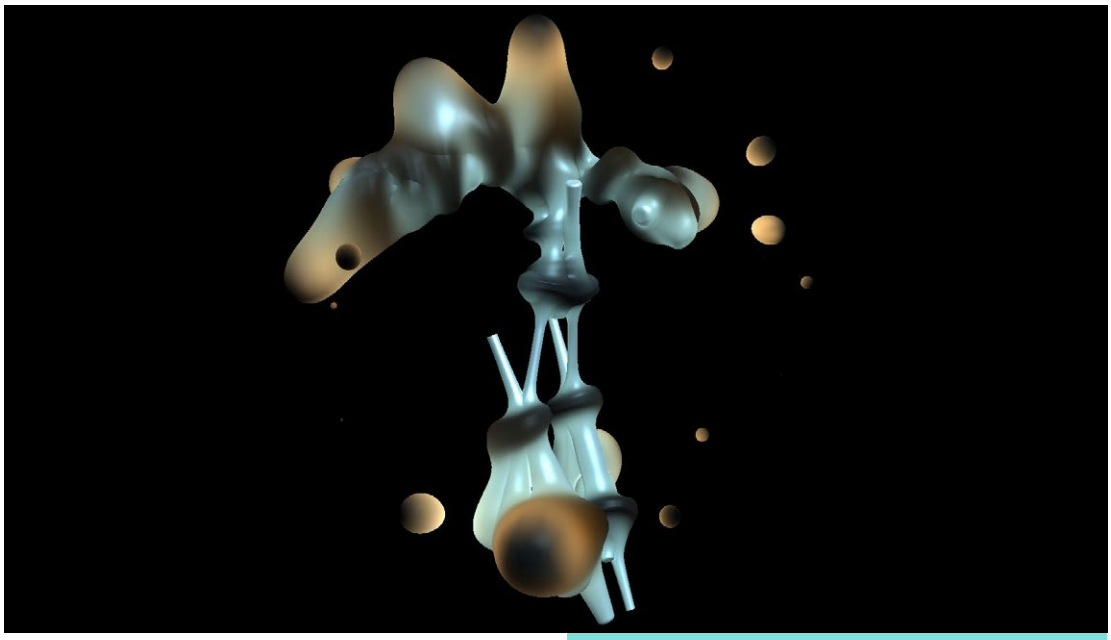


Fig. 4. Screenshot of a graphical rendering of the avatar and sound points. The rendering employs the *Ray marching* technique.

that combines technical-mathematical and natural-human-like properties and merges with the digital instrument in which it is embedded. An example animation is available online.[2] This animation illustrates the rendering of the dancing avatar and sound points using several different parameter settings for the *Ray marching* technique.

Presentation

Sonosphere can be presented at xCoAx 2025 as a concert performance. The musical and choreographic material that provides the content for the presentation stems from several artistic works that have been realized by students and lecturers at the Hochschule Offenburg in collaboration with dancer Marcella Centenero. The titles of these works, their authors, and year of creation are listed in table 1.

Title	Authors	Year of Creation
Dream	Chiara Ehret, Andreas Higel, Maximilian Maurer	2023
Harmonic Orbit	Selina Cuffaro, Alina Engler, Sergej Günter, Nico Neubert	2023
Interface Dance	Magdalena Juarez, Pascal Hohlfeld, Marc Ullrich	2024
Shopping	Habiba Ghanaim, Nicole Stadnik, Selin Öztürk	2024
Music for Human and Object Movements	Ephraim Wegner	2024
Chinese Room	Daniel Bisig	2024

Table 1. Artistic Works. The table lists the artistic works that we realized for the *Sonosphere* by students and lecturers at Hochschule Offenburg in collaboration with dancer Marcella Centenero.

Most of these works are documented with two videos each. One video shows the dancer improvising with the sound sphere while being motion captured. The other video shows a screen performance with the motion-generating AI model as an improvisation partner. These videos are available online.[3]

Concert

During the concert, Daniel Bisig and Ephraim Wegner will re-mix the artistic works that had previously been created for the *Sonosphere*. The re-mix involves the manipulation of the parameters for audio playback and image rendering and the interaction with the motion-generating AI.

Acknowledgments. First and foremost, the authors would like to thank the dancer Marcella Centenero for dedicating her creativity and talent to the collaborative creation of artistic content for the *Sonosphere* and for contributing her movements to the training of the generative AI. Special thanks also go to the students of Hochschule Offenburg who have worked intensively on their artistic realizations. Additional thanks go to the members of the Advanced Motion Lab Offenburg, in particular Prof. Dr. Steffen Willwacher for permitting us to use their motion capture system and to PhD student Mario Kanjuh for providing technical advice and support.

Notes

1. Qualisys Miqus Motion Capture System: https://www.qualisys.com/cameras/miqus/.

2. Ray marching-based Renderings of the Avatar and Sound Points: https://vimeo.com/1056474449.

3. Dream - Screen Performance: https://vimeo.com/1057223470/f09b8c1821.
Harmonic Orbit - Screen Performance: https://vimeo.com/1056476990/5af8a94d59.
Interface Dance - Dance Improvisation: https://vimeo.com/1057564946/d560c59853.
Interface Dance - Screen Performance: https://vimeo.com/1056507731/2fe08ea4a7.
Shopping - Dance Improvisation: https://vimeo.com/1056493554/4a8b3d5139.
Shopping - Screen Performance: https://vimeo.com/1056509177/f4102929bc.
Music for Human and Object Movements - Dance Improvisation: https://vimeo.com/1056498669/cddfc46ed8.
Music for Human and Object Movements - Screen Performance: https://vimeo.com/1057226829/cba53c183f.
Chinese Room - Dance Improvisation: https://vimeo.com/1056504907/0373bb0cbe.
Chinese Room - Screen Performance: https://vimeo.com/1056758658/03bd3901b6.

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Translating Desire: A Lecture Performance about Space Sexology, Gender Identity, and Music

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Dundee, UK
2025.xCoAx.org



Space sexology, gender identity, and music: It sounds exciting, but what is the connection? It is the human body as a musical source and interface for tactile stimulation and sexual arousal. Art, science, and technology are creating new forms of intimacy and sensory perception. An innovative piece of clothing called the Pleasure Spacesuit makes it possible. It transforms the wearer into a musical instrument driven by devotion and desire for oneself, human beings, and cosmic entities. Moreover, the lecture performance *Translating Desire* raises questions about the intertwining of science fiction, space travel, and gender identity. Despite their male biology, the performer expresses their lifelong desire to become Cassiopeia, a Multi-Gender Science Spacegirl. Their mission is to promote the Spacegirl Science Academy project *Cosmic Caresse: The Future of Intimacy in Space*. For them, performative experiments are a medium with which they can let their imagination run wild and reveal their hidden fantasies. Cassiopeia uses medical sensors and computation to translate their sexual arousal into art and music. The tactile stimulators of their Pleasure Suit are controlled by music played by the performer or a musician, as well as data generated by human physiology, environmental sensors, and cosmic phenomena.

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Keywords Sonification, Sexual Arousal, Space Sexology, Pleasure Spacesuit, Gender Identity, Human-Machine Interaction, Intimacy in Space

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Identity and Motivation

“I’m Cassiopeia, an independent multigender science spacegirl.” This is the unexpected answer when I am asked about my sexual orientation and gender identity. It marks the current state of my fragmented development of desire and dedication, from my childhood fascination for female astronauts in shiny spacesuits to adolescent fantasies about scientific experiments in the sex laboratories of Masters & Johnson (Masters and Johnson 1966). My deep connection to music also shaped my life: playing tender chords on a guitar, listening to cosmic music from Tangerine Dream (Tangerine Dream 2025), and much more. At that time, I discovered music as a beautiful way to perceive and develop the female components of my sexuality.

Later, I started cosplaying Sci-Fi Anime Girls and found that computer technology could improve the expressions of my gender identity. Besides, it showed me how much fun it is to be an artist and to incorporate experimental music into my life. I realized that the fusion of biosensor technology with performance art, exemplified by Carolee Schneemann (Ragona 2021), Marco Donnarumma (Donnarumma 2011), and Betty Apple (Kordoski 2021), offered radical new ways of revealing the hidden side of corporeality and identity.

I wondered how I could translate my desire into art and music. It was sonification and visualization of sexual arousal. And when I discovered a new scientific field called Space Sexology (Dubé et al. 2021), the puzzle was complete. In parallel, I learned from Donna Drucker’s *The Machines of Sex Research* (Drucker 2014) how medical technology and social norms are intertwined.

The complexity of my existence showed me that I was multigender (Nonbinary Wiki 2025): female, male, androgynous, femme, and more.

It is essential to say that I use art and music not only to express my personality. I also want to focus on the beauty of sexuality. Eroticism, sexuality, and intimacy are not the work of the devil. They are a divine gift and a central component of life. This is the core message of my current artistic activities.

To make my goals comprehensive, I have created a story in which my body, the “Cosmic Caresse Pleasure Spacesuit” (Arnold 2025), and interactive music software are the core elements.

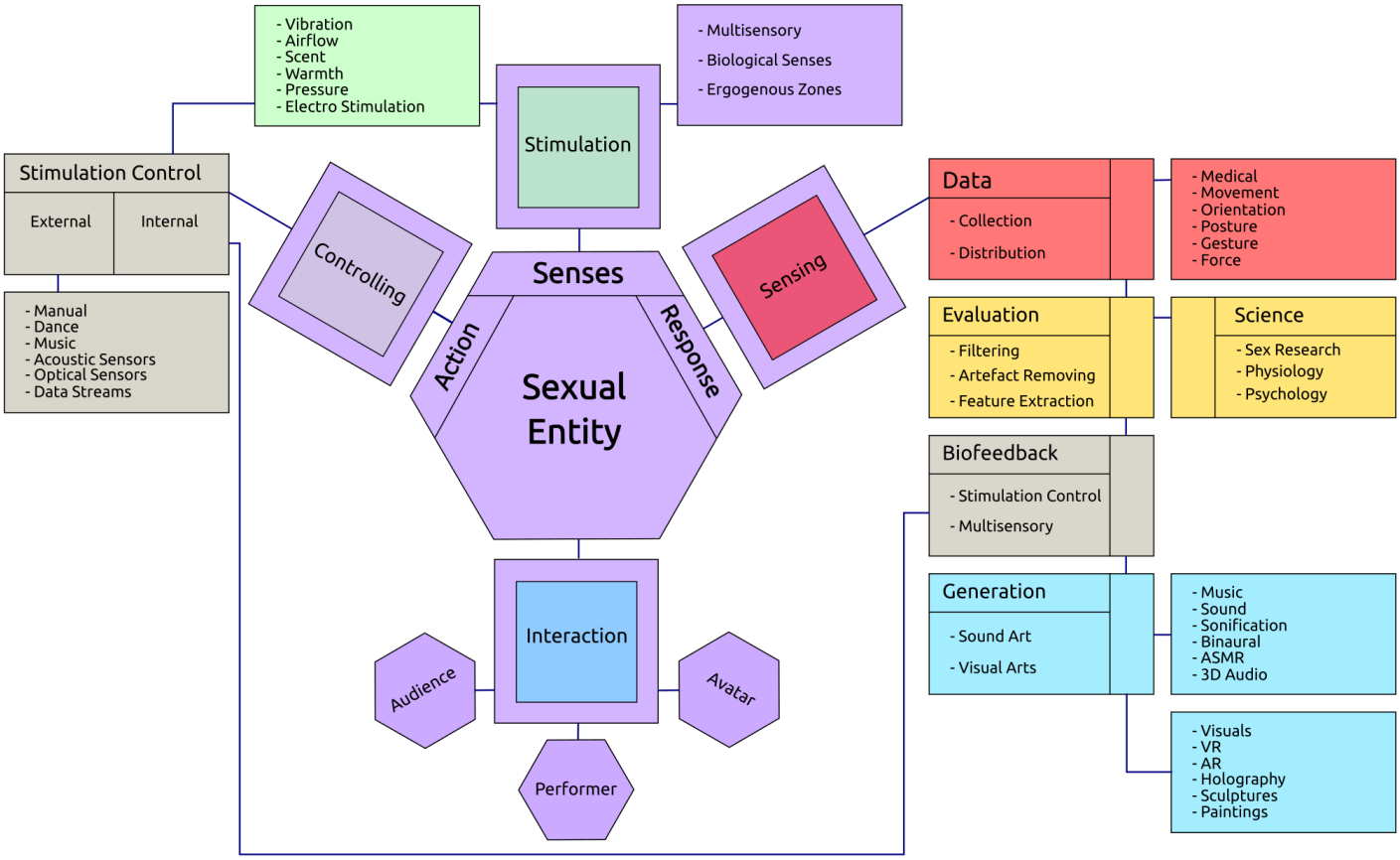


Fig. 1. Possibilities for the performance of sexual arousal.

Structures

My primary interest as an experimental musician is integrating sensors to create and manipulate soundscapes. This was done with electronics and computer technology so that I could include performative elements such as gesture, attitude, and movement in the performance. In this context, the proceedings of xCoAx (xCoAx 2024) and NIME (NIME 2024) proved to be a real treasure chest of innovative ideas. Later, I started using biosensors, which brought me closer to my intention of expressing my gender identity and the associated sexual sensations through art and music. Figure 1 shows my attempt to obtain an overarching structural approach.

In the middle, I use the term “Sexual Entity” because it does not necessarily have to be me, but it can be an artificial intelligence or a robot. In its complexity, the diagram shows many possibilities for designing the performance and explains that this can only be done by extensive computation. The performance requires, inter alia, consideration of the scientific basis of the subject – in this case, the psychophysiological aspects of human sexuality. By structuring these elements so openly, I want to encourage viewers to challenge the social taboos surrounding sexual data, technology, and identity.

Science and Technology

The concept of a Pleasure Spacesuit (Arnold 2025) was inspired by essential themes in space sexology (Dubé et al. 2021). The suit aims to enable sexual relaxation and research in space while maintaining privacy in a confined environment. It is based on vibrotactile stimulation of erogenous zones and uses integrated medical sensors to assess sexual response for scientific experiments.

For the performance Translating Desire, the data from the sensors is also used for real-time sonification of sexual arousal. In addition to standard signals such as pulse, galvanic skin response, and respiration, pelvic muscle tension is also used because it is a reliable indicator of sexual arousal and orgasm (Bohlen and Held 1979) caused by vibrotactile stimulation of erogenous zones (Nummenmaa et al. 2016, 1207-1216). It is essential to say that measuring pelvic muscle tension is gender-neutral, unlike vaginal blood flow or penile erection. Here, measurements are taken with a small anal probe shown in Figure 2. The basic structure is 3D printed, and the shaft is surrounded by a wrapped silicone tube. The tube is attached to a pressure sensor that is connected to an Arduino-compatible microprocessor board. The probe is the most important component of a system for the sonification of sexual arousal (Arnold 2020, 250-270). This is a medical sensor, not a sex toy.



Fig. 2. Anal pressure sensor.

Putting such technologies in the context of future space travel, I point out that intimacy is not separable from scientific innovation. When astronauts wear these suits, the question of how desire, gender identity, and technology intersect becomes deeply profound.

Interactive Sonification

Although the sonification of biosignals is widespread in live performances, for example, in the work of Atau Tanaka (Tanaka 2012, 159-169), the real-time sonification of genital sexual arousal and orgasm is still unique, innovative, and provocative. The readings from the biosensors are fed into a system of Arduino-compatible devices distributed via the OSC protocol. After feature extraction and mathematical processes, additional data, such as heart rate variability, is generated. Then, all are converted to music in real time.

However, music does not only serve to make psychophysiological reactions audible. It is also used to manipulate the speed and patterns of the vibrators hidden beneath the Pleasure Spacesuit's surface (Arnold 2020, 250-270). Therefore, no explicit action, such as touching my body, is necessary to stimulate erogenous zones. When I play

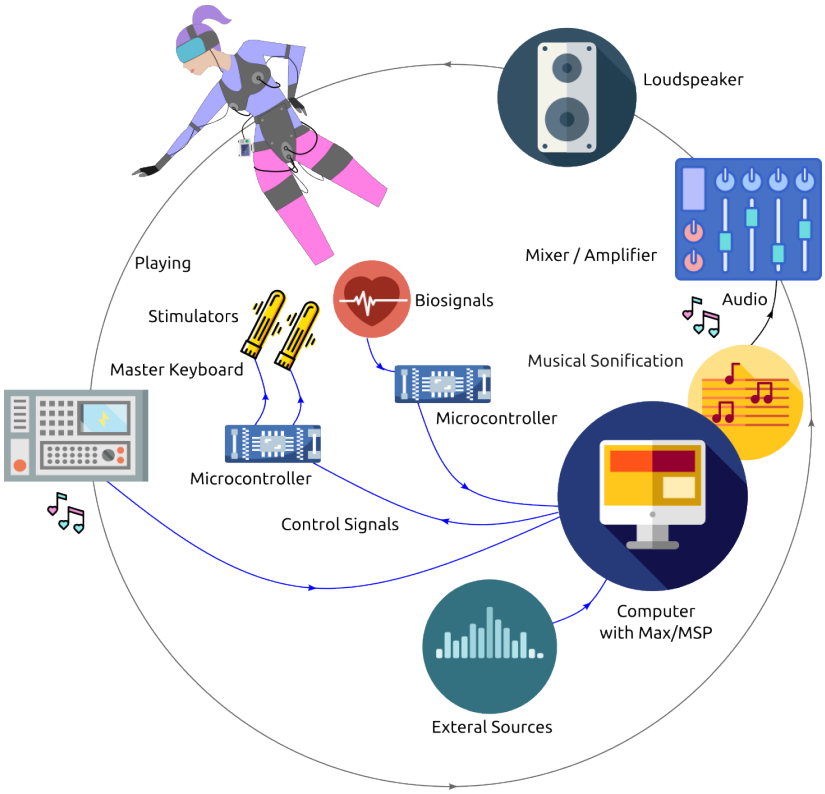


Fig. 3. Stimulation and Sonification Loop.

the controlling instrument, for example, a synthesizer, I express love, tenderness, sensuality, and desire only through music. Ultimately, combining music from both sources creates a stirring symphony of bliss. The resulting feedback loop, in which my sensual body serves as a musical interface, is shown in Figure 3.

The principle is simple: music controls vibrators, vibrators increase sexual arousal, and sexual arousal causes pelvic muscle tension. This tension is measured and controls pitch, as shown in Figure 4, and other parameters of the computer-generated sound. Primary mapping of sexual arousal to pitch reflects the vocalization of arousal and orgasm. In addition, the pulse and galvanic skin reactions also affect the timbral shifts, the layered harmonic progressions, and the generative rhythmic structures, thus creating a dynamic and evolving sonic experience for the listener. The human body thus becomes an erotic musical instrument.

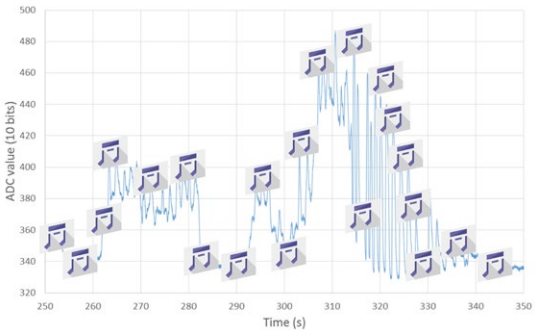


Fig. 4. Mapping pelvic muscle tension to pitch.

Performance

Translating Desire is breaking taboos! The taboo to make sexual acts a central topic of live performances. (Schiel 2020) The taboo to make the sensual human body a tactile interface of musical expression of gender identity. The taboo of intimacy with non-human entities, such as celestial bodies. The enactment does this without explicit action, nudity, vocalization, or dirty talking.

Research

The enactment is also an open psychophysiological study. Pelvic muscle tension, pulse, and skin conductivity are recorded. Later, the graphs and the generated sounds will be analyzed to reveal hidden correlations. Different mapping schemes test whether the musical timbre, pitch, or rhythm best represent these patterns and how they reshape internal imagery, memory, and excitement. As an option, so-called assistants will provide external stimuli. Their pulse rate will be measured to analyze interpersonal psychophysiological aspects roughly. The influence of the material and design of the Pleasure Suit on Cassiopeia's arousal is also the subject of the performative research.

Stage Outfit

To emphasize the futuristic aspect, the fashion design of the Cassiopeia Pleasure Suit is a shiny catsuit with cables and tubes leading to a logging device. (Figure 5) A visor covers their face. In this outfit, they do not just look like a cyborg. They are one. The pleasure suit serves as both a physical extension and an artistic system that makes emotional and erotic connections visible.

Stage Arrangement

Translating Desire unfolds as a live space sexology lab demonstration. Cassiopeia sits in an office chair at a small control desk on stage left, surrounded by a laptop, master keyboard, and the interface panel of the Pleasure Spacesuit. Center stage, a large projection is split into three windows:

1. Protocol – brief scrolling text and diagrams explain each phase.
2. Stimulation Monitor – bar graphs display vibrator intensities.
3. Biosignal Monitor – line charts and numerical data show pelvic muscle tension, heart rate, GSR, and other physiological parameters.

On the right stage is a waist-high tripod with a second master keyboard, an ear-clip heart rate monitor, and a belt with small tactile stimulators that audience volunteers can use.

Storyline

The show has three main parts: 'Listen to your body', 'Express yourself', and 'Get Connected'. These parts build on each other, allowing the audience to understand the technology, the research background, and the musical elements that express Cassiopeia's excitement and sexual response.



Fig. 5. Pleasure Spacesuit Prototype.

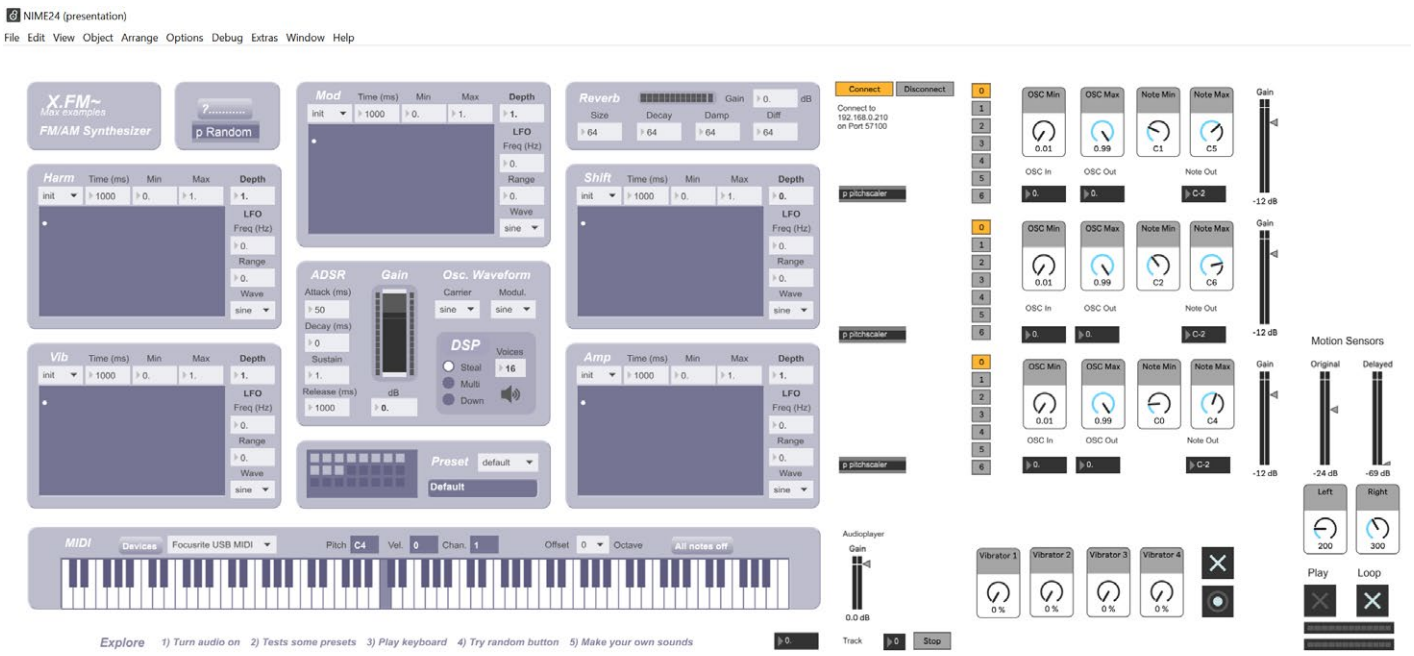


Fig. 6. Max/MSP patch in presentation mode.

Listen to Your Body

The first part is called Listen to Your Body. Cassiopeia activates the vibrators in their suit and listens to the sonification of their sexual arousal. The vibrators are controlled using buttons on a MIDI keyboard. The sound parameters can be influenced via Max/MSP (Figure 6), OSC, MIDI, a master keyboard, and a separate MIDI controller. The intensity of the vibrators is displayed on the projection screen and made audible by low-frequency oscillation. In addition to sonification, the biosignals of Cassiopeia are projected in the style of a patient monitor.

Express Yourself

"Express Yourself" is the title of the next part. Cassiopeia plays music on a synthesizer to express their feelings and connect with the audience. The synthesizer also generates control signals for the suit's tactile stimulators. Their music and the sounds of their sexual arousal combine, creating a feedback loop that results in a strange sonic construct. This interaction shows how the performer's inner desires are externalized by sound and visual signals, bridging the gap between personal fantasy and the collective experience.

Get Connected

In the third part, "Get Connected," Cassiopeia's stimulation is influenced by external signals. These signals can be generated by previously recruited volunteers from the audience as Assistants. To hide their identities, they wear lab coats and medical masks. They use a master keyboard and have some options to control the intensity of the vibrators:

- Directly using knobs and sliders.
- Play music, referring to “Barbarella’s Excessive Machine”. (Lesage and Flinn 2022)
- Manipulate previously sonified satellite data from supernova Cassiopeia A. (NASA Chandra X-ray Center 2021)

In addition, the Assistants can decide whether to use a pulse sensor to incorporate their reactions into the performance. They are also free to use belts with small tactile stimulators, manipulated by signals from the Pleasure Suit.

This underlines the idea that, in the name of science, a shared experience of dominance, devotion, and empathy is emerging. It envisions a future of intimacy in space through the interaction of bodies, technology, and space.

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Currents & Tides: An Exploration of Generative Music in Three Acts

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Dundee, UK
2025.xCoAx.org





Currents & Tides is an electronic music performance in three acts. The piece integrates digital and analog music, generative audiovisuals and vocals into three distinct parts and expands from stereo to multichannel audio. Each part is an individual musical piece that introduces a unique artistic perspective on generative music and audiovisual interaction. The performance evolves over time through the individual acts, with each subsequent act incorporating elements from the previous one. This way a connection between them is created which culminates in a unified whole, figuratively referred to as interplay between *currents* and *tides*. The performance title thereby also references the workshop series *Making Waves*, during which the individual parts and the overall concept were developed. *Making Waves* is dedicated to exploring music technologies and serves as an experimentation platform for participants from diverse disciplines, including those with and without a musical background, to engage in music-making and live performance.

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Keywords Audiovisuals, Multimodality, Generative Art & Design, Music, Sound Art, Performance

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Background

The electronic live music performance *Currents & Tides* is a result of the *Making Waves* workshop series held within the Creative Technologies Master's program at the Filmuniversität Babelsberg. Making Waves aims to familiarize students with music technologies and the process of music-making itself. Participants have the opportunity to experiment with new tools, learn about various forms of musical or artistic expression, and co-create electronic music. The didactic method is project based and combines theoretical input with hands-on application.

Initially, the workshop focused on exploring the use of AI-based tools for music composition and production. However, at the same time it became clear that the participants had a fundamental interest in making music in a broader sense. The exploration of new musical devices, generative systems or spatial audio in combination with the opportunity to learn about songwriting, sound synthesis or sequencing to create and present their own musical pieces is particularly attractive. The workshop has embraced the concept of 'musicking'[1] to a greater extent and aims to facilitate a holistic approach to crafting, performing and experiencing music as presented by Brown in his discussion on the benefits of meaningful engagement[2] with music (Brown 2007). Future topics such as live coding or the development of custom instruments using physical computing devices are currently being explored, drawing inspiration from (Hepworth et al. 2019), for example.

Making Waves is open to students from various disciplines; prior knowledge in the field of electronic music is not required. Yet most participants have at least some experiences in musical activities. Each course concludes with a live performance of the pieces developed, which is highly appreciated by the participants and has provided an impetus for the development of *Currents & Tides*.

Currents & Tides

Currents & Tides is an electronic live music performance divided into three individual acts. Each act builds on the previous one and adds a new modality to the performance, driving forward the musical and audiovisual development of the overall piece. The performance is still work in progress and has evolved from an earlier version that was conceived for an anniversary celebration at the Filmuniversität Babelsberg in Nov. 2024.

This initial performance consisted of four mainly independent pieces



Fig. 1. Left: Performance stage with laptops, four Astera Titan Tubes of the lighting setup and projection screen in the background. Right: A modular setup of one of the performers, anniversary celebration at Filmuniversität Babelsberg, Nov. 2024. Image courtesy of Andreea-Cristina Mircea.

of generative music. Three of them additionally generated visuals that were projected onto a screen positioned behind the performers using a near screen projector. To create an overall theme, an audio-reactive lighting concept was introduced. All performers sent OSC messages wirelessly to a lighting console which controlled various light tubes via Touch Designer. This way, the lighting was driven by the individual sonic or visual parts while serving as a common element and providing great ambience (see Fig. 1).

In the revised iteration presented here, the focus is put on a closer conceptual connection between the individual parts. The first act begins with beat-heavy drone sounds designed to connect performer, space, and audience. The second act builds upon this foundation and adds a visual layer that integrates with the music. In the third and last act, the sound field opens up into the audience space with the use of multichannel playback and live vocals. The performance thus evolves from stereo sound to an audiovisual experience into spatial audio with live vocals, all while preserving the uniqueness of the individual artistic approach and the respective exploration of generative music.

Act I | Tidal Drift

Tidal Drift by Kontrol Voltaj (Elena Vasilkova, see Fig. 2) provides the fundamental layer for *Currents & Tides* and acts as an atmospheric element designed to immerse the listener. It functions as a means to experiment with different techniques in generative composition, sound design and synthesis. As the rhythmic, harmonic, and textural base of the performance, the sonic framework sets the emotional tone and atmosphere.

Central to this approach is the use of modulators that influence each other in a feedback-inspired system. By modulating each other, the sound elements form a self-sustaining network, driving continuous change and organic evolution. This allows for complex textures, where sounds emerge, interact, and dissolve organically. Extensive use of reverberation further amplifies spatial depth. Rhythmic ele-

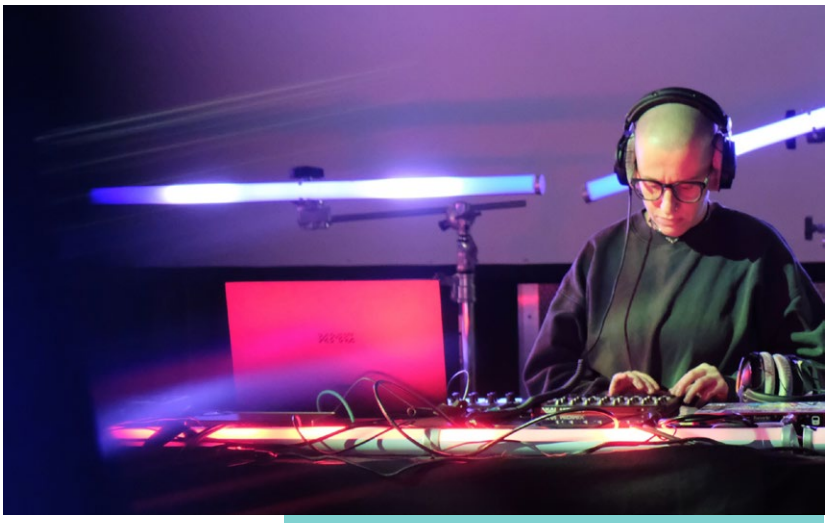


Fig. 2. Kontrol Voltaj (Elena Vasilkova) performing at Filmuniversität Babelsberg on the occasion of the 70th anniversary celebrations, Nov 2024, in Potsdam. Image courtesy of Andreea-Cristina Mircea.

ments, constructed with generative sequencing, randomness, and modulation, maintain unpredictability and flow, while melodic fragments feed into each other, sometimes fading and re-emerging, creating a sense of constant transformation. The work draws inspiration from a variety of electronic genres, including ambient, drone, noise, techno, and electro, blending these influences into a cohesive, immersive sonic environment.

The development of this layer was highly experimental, with a focus on sound design, improvisation, and iterative refinement. The Torso T-1 generative sequencer acted as the "brain" of the composition, driving evolving rhythms and melodies with inherent randomness. Sound synthesis, granular processing, and real-time modulation created rich textures, while reverberation and feedback systems enhanced the immersive experience. As sound sources, software synthesizers on PC and iPad were utilized, contributing to the versatility of the sonic palette and including applications such as Opal by Fors, Arturia Pigments or Tera Pro.

Act II | Multimodal Recursions

Multimodal Recursions by Joel Schäfer and Anna Ferro (see Fig. 3) aims to engage the audience with both audio and visuals. The piece is composed of three chapters: starting from an atmospheric and harmonic setting, it evolves into a more technologized realm of glitches, digital errors and punchy drum breaks, before dissolving into abstract soundscapes inspired by noise music. The approach aims to go beyond audio reactivity as a method of multimodal expression, but rather to create a deep entanglement of auditory and visual synthesis and processing techniques. This is achieved through a non-hierarchical, interconnected modulation system, where visual parameters control sound parameters and vice versa in an experimental audiovisual dialogue.



Fig. 3. Joel Schäfer (left) and Anna Ferro (right) performing with collaborator Elisabeth Scholz (middle) at Filmuniversität Babelsberg on the occasion of the 70th anniversary celebrations, Nov 2024, in Potsdam. Images courtesy of Andreea-Cristina Mircea.

This artistic practice emerged from the experimental development of each individual chapter, loosely interconnected to form an uncertain yet harmonious audiovisual journey. By using feedback loops between sound and video, the two elements dynamically interact, introducing unpredictability into the composition. The generative dimension arises from real-time analysis of the audiovisual content, which is fed back into the synthesis process, creating cyclical interactions where rhythmic glitches and patterns manifest simultaneously across both domains. The system continuously analyzes and reintegrates the outputs, forming an ever-evolving feedback loop in which sound and visuals reciprocally shape the work's shifting identity.

On the musical side, this approach was developed using a custom modular synthesizer system, an electronic drum machine, a tongue drum with a pickup microphone and several digital audio effects such as reverbs and granular processors from within the Ableton Live DAW. The visual aspect was developed through algorithmic and generative video using Touch Designer and controlled by a MIDI controller. In addition, a network switch is used to transfer data via the UDP-based Open Sound Control protocol, allowing the bi-directional sending and receiving of modulation data and triggers within the entire audiovisual system.

Act III | Hybrid Rituals

Hybrid Rituals by Vocalist *NINANIÑA* (Andreea-Cristina Mircea) and visual artist-producer *Ay Din* (Aydin Thill) bridges tradition and technology and forms a dialogue between human expression and digital transformation. Historically, rituals often fostered collective experiences and this is what the final act reinterprets. The human voice is used to directly interact with and reshape a generative virtual world; natural and digital merge into a fluid, responsive environment (see Fig. 4).



Fig. 4. The environment scene created with UNREAL Engine for the final act *Hybrid Rituals*.

Image courtesy of Aydin Thill.

The act draws inspiration from traditional vocal practices from various cultures around the world. At the core of the act are NINANIÑA's live vocal improvisations. The vocals are transmitted from Ableton Live to Unreal Engine, where they serve as dynamic triggers, orchestrating the movement of virtual avatars. This interplay transforms the voice into an agent of generative composition, expanding the performance into a participatory exchange between human and digital entities. Throughout the act, visual and sonic elements from the preceding two performances are subtly reintroduced – either as hidden reference embedded within the digital landscape or as sampled material woven into the musical composition. This creates a cohesive narrative thread across the three individual acts.

A key element of the final act is the shift from stereo to four-channel audio. This change is designed to enhance the transition from a one- or two-dimensional sound and audiovisual experience to a multi-dimensional space, the hybrid realm. Here, the collective extends beyond the physical, incorporating digital embodiments that respond to musical and environmental shifts. The performance space is designed using the Unreal Engine, with generative audiovisual elements reacting in real time to the evolving musical structure. A modular Ableton Live setup incorporates spatial audio, microtonal scales, and live sampling, immersing the audience in an unfolding sonic space that bridges ancient practices and future technologies.

Conclusion

The performance *Currents & Tides* shows the wide array of musical possibilities that a hands-on workshop format like *Making Waves* can put forth. Through exploration of different tools, personal inspirations from the entire spectrum of electronic music, and groups' influence on each other during the formation process, the participants created very unique and forward-thinking pieces.

One challenge that arises from the freedom of the process is the one of sculpting a cohesive performance for the audience. In the anniversary celebration performance coming out of *Making Waves*, audio-reactive ambient lighting was employed to achieve this cohesiveness. This was effective but lacked a coherent dramaturgical thread. To address this, *Currents & Tides* puts focus on the concep-tual side of the performance as a whole. The individual acts form a multimodal experience that evolves from stereo to four-channel experience, engaging with various generative music, audiovisuals, and live vocal improvisations. While this work is still in progress, the performance has moved beyond a mere sequence of individual parts. Future iterations may further integrate the previous light art approach with new ideas.

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Gen AI. The authors used ChatGPT and Deepseek for spell-checking, better wording, translations.

Notes

1. The term 'musicking' was introduced by Christopher Small in his work "Musicking: The Meanings of Performing and Listening" and addresses the interdisciplinary and socio-cultural aspects of music making, presenting, and experiencing (Small 1998).

2. Brown identifies five aspects by which students can be engaged with music, i.e., appreciating, evaluating, directing, exploring, and embodying, all of which are increasingly included into Making Waves lesson planning.

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Andrea González Garrán
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